Results of the 1993 System Dynamics Society Benchmarking Study

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Abstract

The lack of commonly held rules or standards for system dynamics, the eclecticism of its application, and the wide variety of modeling and non-modeling methodologies developed over the past thirty years present formidable challenges for establishing an effectively functioning system dynamics community. It is reasonable to suggest that the current structure of the community may hold back the growth of the field more than obvious obstacles such as the inherent difficulty of developing insightful models or the counterintuitive nature of nonlinear feedback lessons. In this light, the structure of the community deserves closer scrutiny.

Benchmarking the System Dynamics Community , a survey sent by the author to System Dynamics Society members in February of 1993, is the first survey of the system dynamics community and a first step towards developing a more comprehensive understanding of the structure of the field. The survey instrument consisted of five sections: Background, Practice, Software and Hardware, Model Building, and History, Development, and Community. The survey was designed to isolate where system dynamics is practiced, by whom, and for what; understand how the methodology is applied; and identify lines of communication across the field.

This paper presents the results of survey responses, structured parallel to the five sections of the survey instrument. It concludes with a series of questions for further investigation.

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Introduction

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Who participated

Over thirty-five percent of the 455 members of the System Dynamics Society participated in the study. Although 28 countries are represented in the study,[1] country-specific analysis is inappropriate due to the small sample size for most countries.

Survey results

Background

Respondents consider themselves active system dynamics practitioners. Seventy percent indicate a level of involvement of "7" or above (out of "10"), while only 13% report their involvement to be under "5". Indeed, respondents are not newcomers to the field: 53% have been involved with system dynamics for over ten years, while 21% have been involved for 5 to 10 years, 22% for between 1 and 5 years, and only 4% for less than 1 year.

As shown in Figure 1, most respondents are male, between the ages of 40 and 55, and hold PhD/DSci degrees. MBAs constitute 37% of the M.A./M.S. degrees, compared with 20% in an engineering discipline. Similarly, the fields of business or management comprise 32% of the PhD/DSci degrees, compared with 15% in an engineering discipline. Of the PhDs, 15% indicate that their degree is explicitly in system dynamics.

Respondents register strong quantitative backgrounds. Sixty-one percent indicate levels of expertise of "advanced" or "expert" in both statistics and mathematics, while less than 20% consider their mathematical or statistical skills to be "basic".

1 All of the 13 countries not represented in the survey responses have two members or less in the System Dynamics Society.

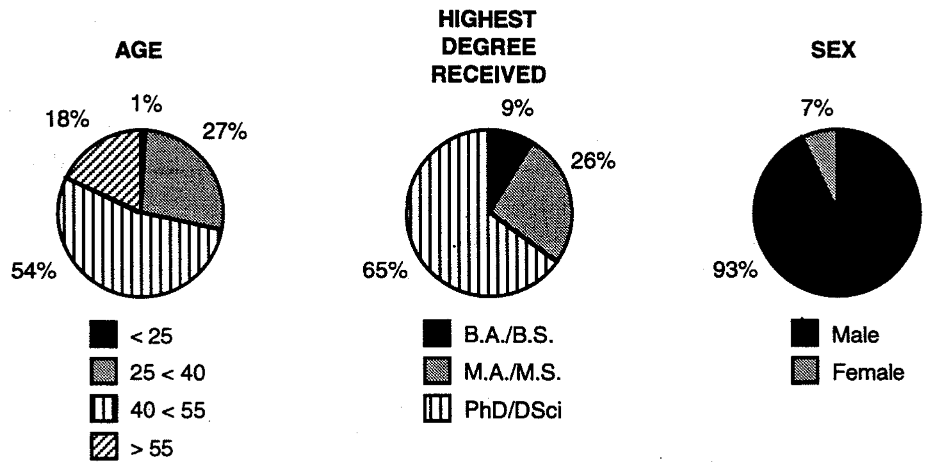


Figure 1: Profile of survey respondents

While 91% of respondents have graduate-level degrees, only 58% have formally studied system dynamics. Figure 2 shows the percent of respondents who have formally studied system dynamics and notes the institutions that sponsored their study. Massachusetts Institute of Technology, Dartmouth College, and State University of New York at Albany sponsored over three-fourths of all formal study, with the remaining 25% shared among 11 American and 8 European universities. Of the top three sponsors, however, only MIT and SUNY–Albany still actively teach system dynamics modeling.

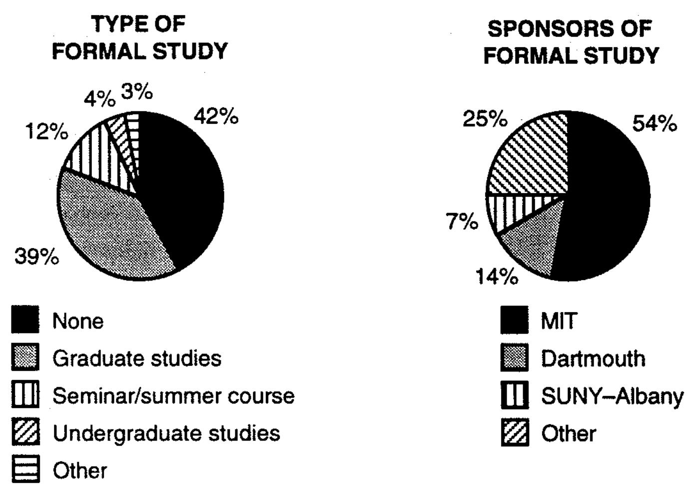


Figure 2: Summary of formal training

Practice

Table 1 shows the areas of application and environments in which respondents apply system dynamics.[2] The majority of respondents are academics, and almost half of all respondents work in the private sector. Most respondents apply system dynamics to business and corporate policy, and a large percent also apply system dynamics to public and social policy.

2 Please note that the categories in Table 1 are not mutually exclusive. A Professor, for example, might also cons to the private sector, and could be involved with business policy, social policy, and system dynamics research.

	ENVIRONMENT			
AREA OF APPLICATION	**Academia**	**Private Sector**	**Public Sector**	**TOTAL**
Business/Corporate Policy	37%	37%	21%	**58%**
Public/Social Policy	32%	21%	25%	**44%**
System Dynamics*	28%	11%	13%	**31%**
Environmental Policy	18%	14%	11%	**25%**
Industrial Policy	14%	9%	9%	**18%**
Other	18%	11%	10%	**25%**
TOTAL	**66%**	**48%**	**35%**	

*Includes teaching and methodological research

Table 1: Practice areas and environments of application

Forty-five percent of all respondents are Professors, almost 70% of the total academic group. Management consultants comprise over 18% of all respondents, and an additional 11% practice system dynamics within a business organization. The high proportion of business and corporate policy practitioners is consistent with the applied (as opposed to methodological) content of the *System Dynamics Review* from 1985 to 1990, but the high share of management consultants contrasts with the near absence of *Review* articles over the same period that relate system dynamics consulting experience (Richardson 1991).

Interestingly, the subset of respondents who indicate a level of involvement of "7" or greater are not concentrated within a specific environment or area of application. When Table 1 is adjusted to reflect only the "active" modeling subset, the relative distributions do not change by more than 1% in any category.

Environment

In all, 58% of respondents practice system dynamics wholly within one type of environment. In Figure 3, the degree of overlap between environments is explored in more detail. Over half of the 66% of respondents in academia practice system dynamics wholly within the academic environment (34% of all respondents). Therefore, almost one-fourth of the Professors who responded also practice system dynamics in the public or private sector.

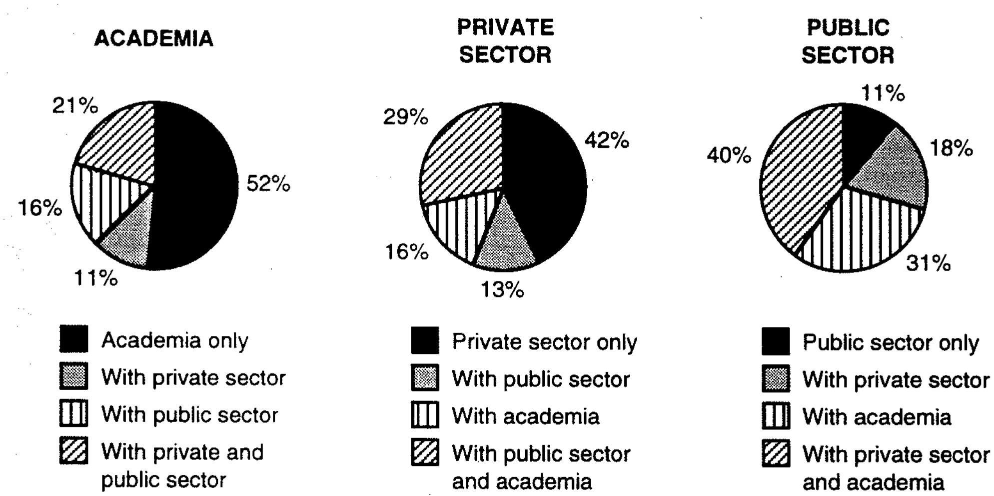


Figure 3: Distribution of environments of respondents

Areas of application

Respondents are less concentrated in their areas of application, with only 38% practicing system dynamics wholly within one area. Figure 4 shows the distribution of the single-area group. Respondents who apply system dynamics to business and corporate policy issues constitute the bulk of the group, with a 59% share.

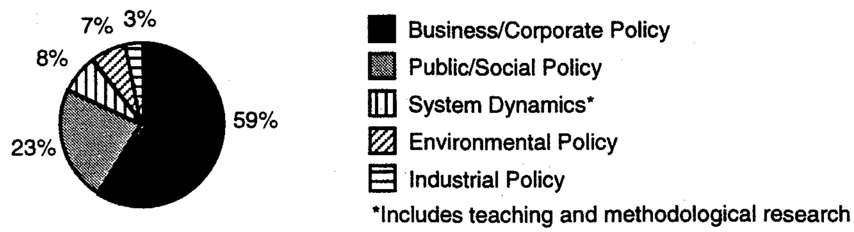


Figure 4: Distribution of single-area respondents

Not surprisingly, within the broad area categories, the specific topics to which respondents apply system dynamics widely vary. Modeling topics range from energy research to pharmaceutical new product modeling; from religion and philosophy to transportation investment; and from issues within the Vermont Department of Corrections system to how technology affects the rise and fall of civilizations. However, evidence suggests that Society membership might largely miss some segments of the system dynamics modeling community.[3]

Model building

Methodology

Not all respondents consider system dynamics to be an isolated area of practice. As one respondent notes, closed form equations are a standard tool in science, engineering, finance, and economics. The majority of respondents, however, seem to agree upon what constitutes system dynamics modeling. As shown in Figure 5, most respondents develop continuous models and feel that models must begin simply, capturing the top-level feedback structures that characterize the system first, and progressing towards a lower level of complexity as these structures are disaggregated into more detail.

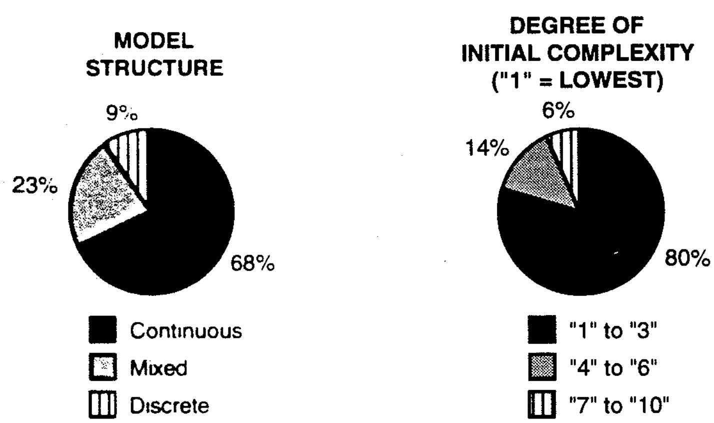


Figure 5: Model structure and approach

3 In particular, conversations with Dr. Carl Way of the U.S. Army Corps of Engineers point to a large ecological modeling community outside of the System Dynamics Society.

Stages in model development

Respondents agree that conceptualization is the most time-intensive model development stage, followed by formulation, improvement, and implementation. Table 2 shows how respondents allocate their time throughout the four stages of a modeling effort (cf. Randers 1980). Note that the column totals do not add to 100%, as some respondents ranked activities equally.

	TIME SPENT ("1" = MOST TIME)				
MODELING ACTIVITY	"1"	"2"	"3"	"4"	TOTAL
Conceptualization	45%	32%	16%	7%	**100%**
Formulation	33%	41%	17%	9%	**100%**
Improvement	17%	24%	40%	19%	**100%**
Implementation*	10%	11%	23%	50%	**94%**

*6% of respondents do not implement their models

Table 2: Time-intensiveness of model development stages

Conceptualization

Respondents primarily use causal loop diagrams to assist in conceptualization:

- 82% of respondents utilize causal loop diagrams
- 70% utilize flow diagrams
- 41% utilize substructure diagrams
- 19% utilize policy structure diagrams.

Formulation and improvement

During the formulation and improvement stages, respondents' use of confidence tests varies (cf. Forrester and Senge 1980). As illustrated in Figure 6, respondents do not appear to apply a "standard" set of confidence tests to their models. Only two tests – structure and parameter verification – are used more than 80% of the time, and some important tests, like dimensional consistency, seem under-utilized.

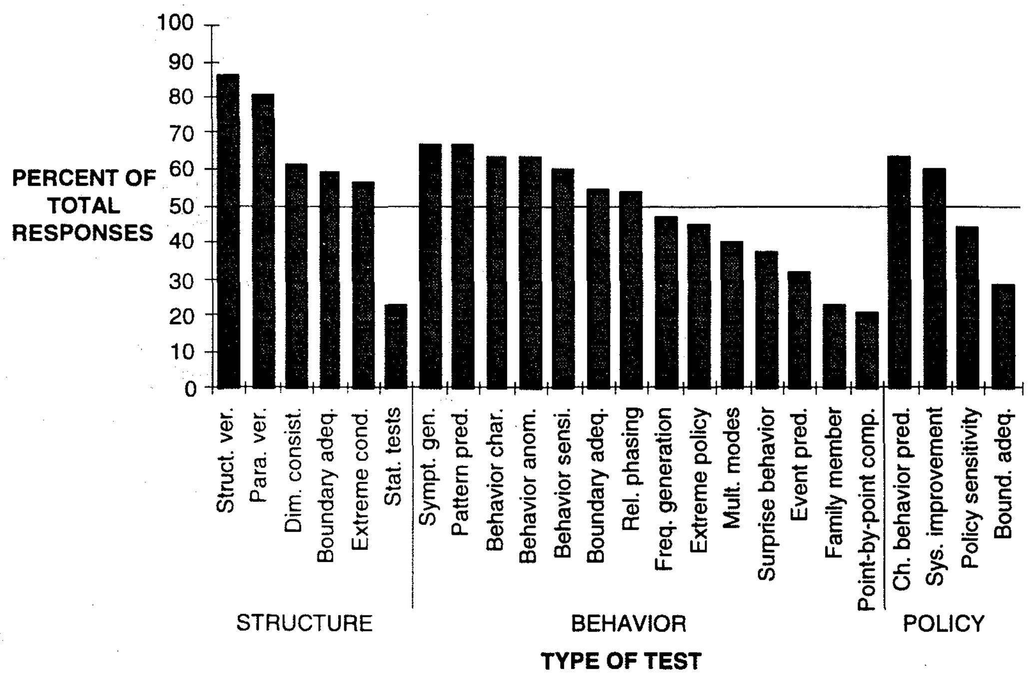


Figure 6: Percent of respondent who use confidence tests

Implementation

Nine percent of respondents in academia do not implement their models, compared with 2% and 3% in the public and private sectors respectively. Of the 94% of respondents who implement their models, most transfer system insights and few transfer a physical model:

- 78% transfer an understanding of the system
- 67% recommend policy changes based upon the model
- 38% implement operational changes based upon the model
- 26% transfer the model itself.

Model types

As illustrated in Table 3, most respondents develop either general understanding or policy formulation models, and a smaller number develop detailed implementation models (cf. Meadows 1980).

	FREQ. OF DEVELOPMENT ("1" = MOST OFTEN)			
MODEL TYPE	"1"	"2"	"3"	TOTAL
General Understanding	42%	26%	11%	**79%**
Policy Formulation	42%	30%	8%	**80%**
Detailed Implementation	15%	13%	19%	**47%**

Table 3: Types of models developed by respondents

Differences appear to exist, however, in the methodologies embraced by developers of different model types. First, Figure 7 shows the type of model structure, degree of initial model complexity, and average number of variables for the subset of total respondents who develop either general understanding, policy formulation or detailed implementation models most often.

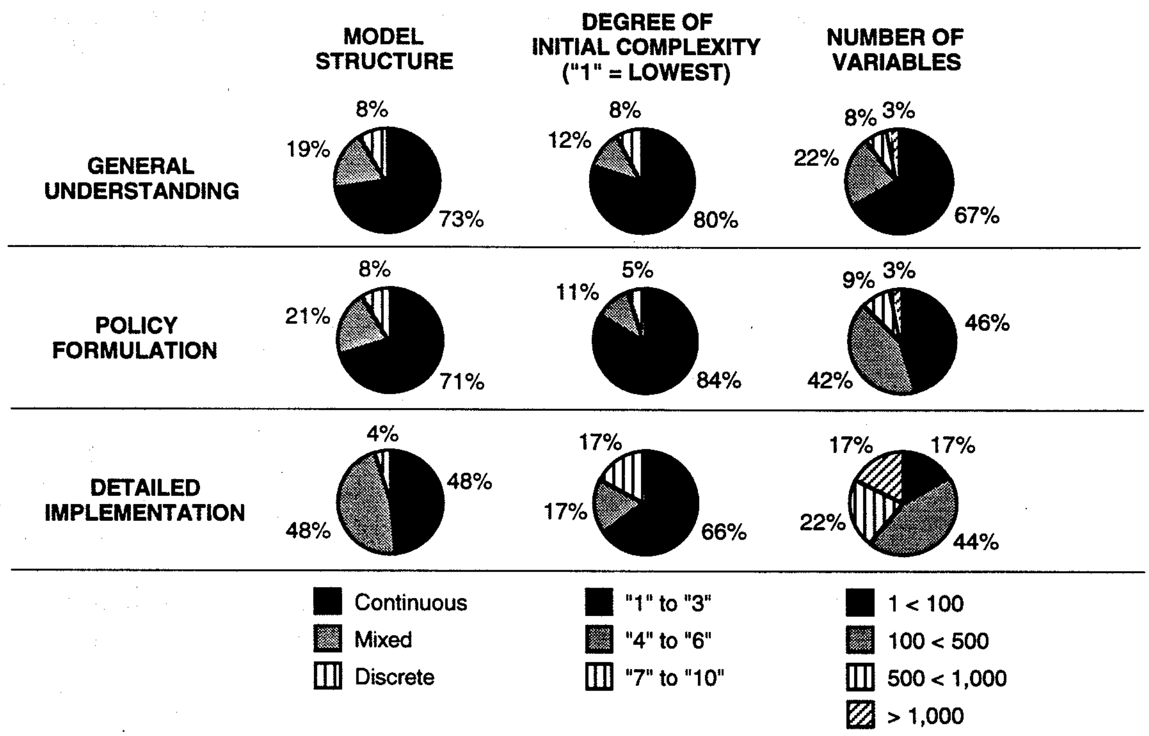


Figure 7: Methodologies by model type developed most often

While respondents who develop general understanding models or policy implication models the most tend to share methodological approaches, respondents who develop detailed implementation models the most show less consensus about modeling practice.

Next, developers of the three model types utilize confidence tests to varying degrees. Respondents who develop detailed implementation models the most apply more rigorous standards to their models. On the surface, this stands to reason – detailed implementation models are likely to be more comprehensive than general understanding models and could require a broader range of confidence tests. A more careful analysis, however, reveals inconsistencies in confidence testing across model types.

Respondents who develop general understanding models the most utilize structural tests the least. Certainly, general understanding models may not require a battery of statistical tests, or point-to-point fidelity with the reference mode. One could argue, however, that structural tests are perhaps most important for general understanding models, as the scope, purpose and audience of a general understanding modeling effort often does not force modeling rigor *a priori*.

On the other hand, respondents who develop general understanding models the most test most frequently for symptom generation, frequency generation, behavior characteristics, pattern prediction and event prediction. To conjecture, these differences could reflect the fact that it is easier to "hard-wire" a simple model to produce expected behavior that, in the absence of rigorous structural testing, might seem robust.

Finally, analysis of critical skill requirements across each of the three model types reveals differences of opinion about the essential skills necessary for effective system dynamics modeling. Figure 8 presents the minimum skill requirements for each model type as judged by respondents who develop that model type most often. Respondents who develop general understanding models the most rate technical modeling ability, mathematical and statistical

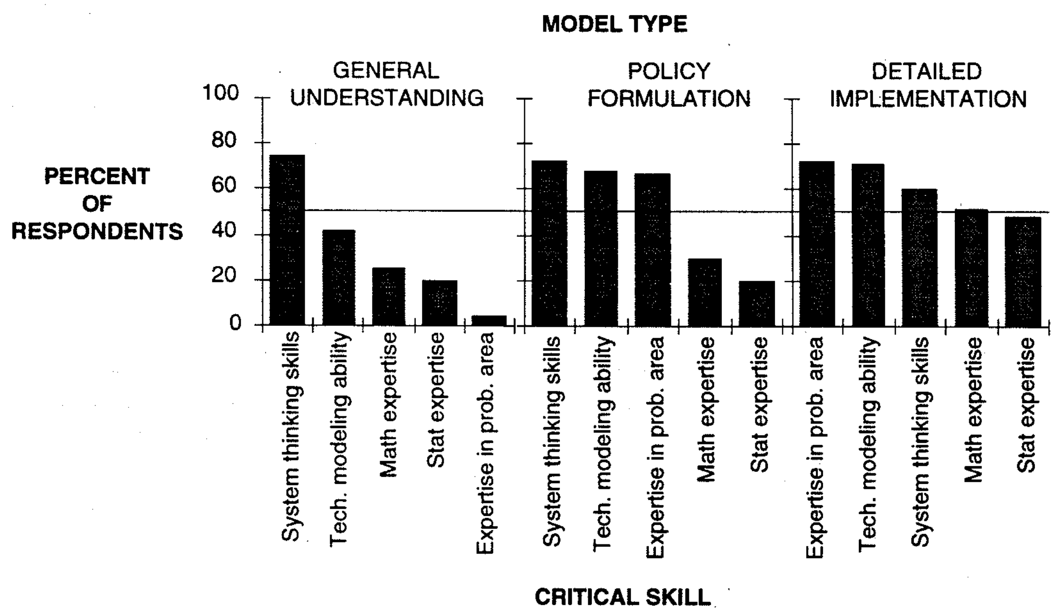


Figure 8: Critical skill requirements by model type

expertise, and expertise in the problem area as non-essential. In contrast, policy formulation and detailed implementation model developers both feel that technical modeling ability is extremely important, and detailed implementation model developers also place a great emphasis on mathematical and statistical expertise. The premium placed on "system thinking skills" by genera understanding modelers in lieu of more rigorous technical modeling ability, combined with their inconsistent use of confidence tests, suggests that a possible lack of robustness may exist across the population of general understanding models.

Software and Hardware

Software

Most respondents use STELLA or iThink to support model development. Figure 9 shows software use among the respondents.

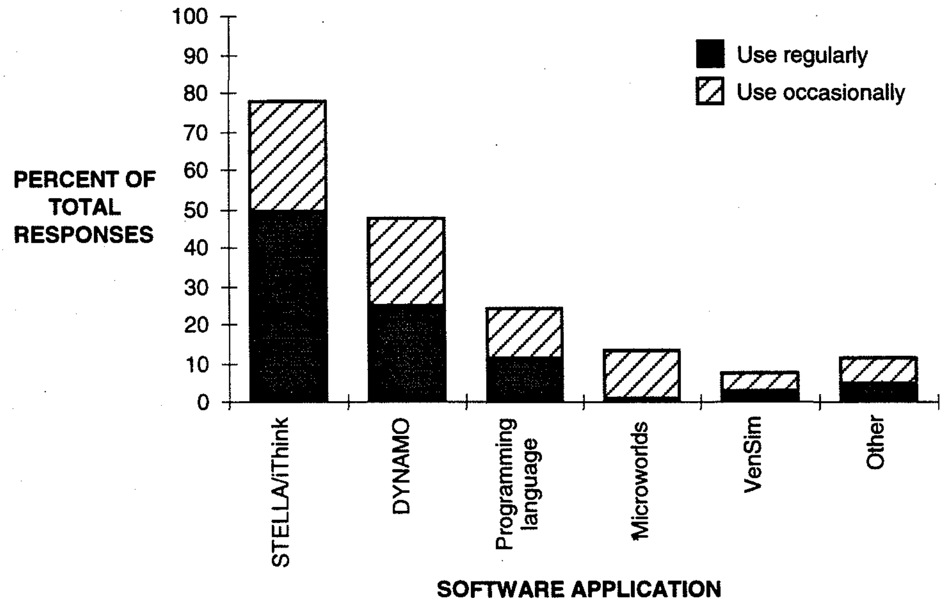


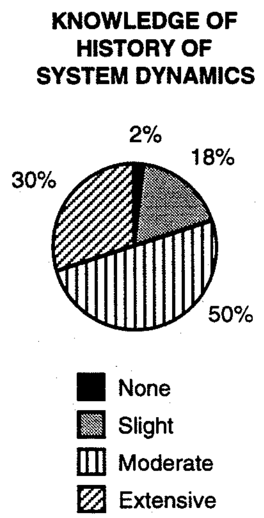
Figure 9: Software used by respondents

Hardware

Sixty-eight percent of respondents use Macintosh computers, 59% use PCs, and 29% use both. Minicomputers and mainframes are each used by 9% of the respondents. Respondents indicate that their choice of a hardware platform is driven primarily by either the requirements of a modeling language or resource availability, and many are frustrated by the lack of cross-platform compatibility among software applications.

History, development, community

On the whole, respondents profess a moderate to extensive familiarity with the history of system dynamics, but read little system dynamics material outside of the *System Dynamics Review* regularly, as shown in Figure 10. Some respondents argue that the *Review* is narrowly focused, and indeed, 35% of the journal's pages are dedicated to methodological issues. However, some maintain that, as the Review is the professional journal of the System Dynamics Society, this methodological focus is to be expected (Richardson 1991).



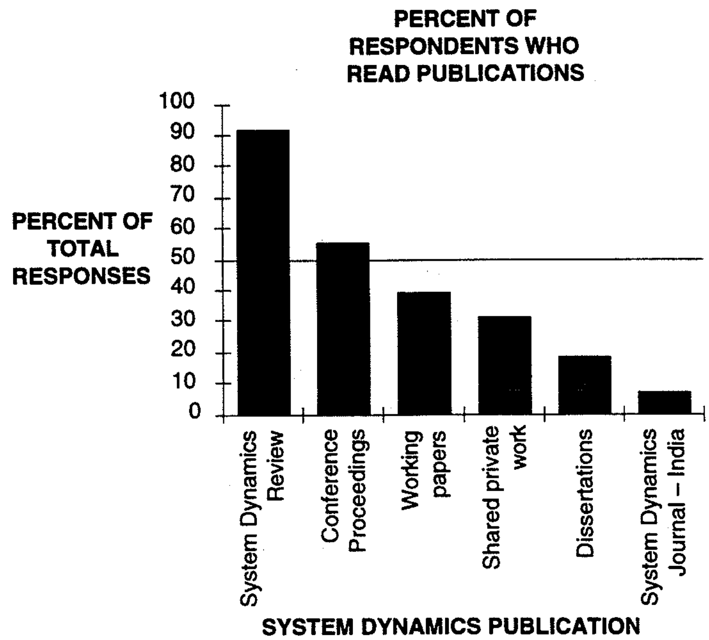


Figure 10: Knowledge of system dynamics history and percent that read publications

Many respondents feel that it is important to follow developments outside of system dynamics and regularly read journals like Management Science, European Journal of Operational Research, International Journal of Systems Science, and the Strategic Management Journal. To that point, several respondents urge that system dynamics must increase its credibility as a problem-solving technique in disciplines like sociology, political science, and economics.

Only 51% of respondents indicate that they are in frequent contact with other practitioners. A number feel "isolated" from practitioners, published models and papers and current modeling software, and stress the need for a broader dissemination of relevant research and development throughout the system dynamics community.

Table 4 presents the top five models and papers or books that respondents cited as most significant in the development of the field. Of the more than 3,300 articles and books in the literature of system dynamics,[4] respondents identified 82 unique works.

CITED MODELS	PERCENT
1. WORLD models	44.0%
2. Industrial Dynamics	21.0%
3. Urban Dynamics	19.0%
4. Market Growth	11.0%
5. National Model	9.0%

CITED PAPERS OR BOOKS	PERCENT
1. Industrial Dynamics	15.0%
2. Counterintuitive Behavior of Social Systems	9.0%
3. Market Growth as Influenced by Capital Investment	8.0%
4. Tests for Building Confidence in System Dynamics Models	6.0%
5. The Fifth Discipline	5.0%

Table 4: Top models and top papers or books

Generally, respondents attribute their selections to the positive contribution of the work to the field. The notable exception was the WORLD models, about which respondents' opinions bifurcated. Some felt that the model put forth a timely and important message, while others felt that the model has given system dynamics a "notoriety" that the field has yet to overcome.

4 For more information about how to receive a bibliography of system dynamics literature, please contact Kip Cooper or William Steinhurst at The International System Dynamics Society, Bibliography Committee, 49 Bedford Road, Lincoln, MA 01773, U.S.A.

Jay Forrester was the most frequently cited author by a significant margin, with 80 citations. Peter Senge was second with 21, followed by John Sterman with 18. George Richardson was fourth wit 12, and John Morecroft fifth with 8.

Questions for further investigation

Ultimately, the 1993 benchmarking study could help the system dynamics community to define questions that may prove critical to the continued development of the field and the greater dissemination of system dynamics concepts worldwide. Based upon the results of the benchmarking, questions for further investigation could include:

- What are the characteristics of a "typical" member of the System Dynamics Society? Do these characteristics meet the criteria that are relevant to problem-solving in the 1990s?
- What is the relationship between system dynamics modeling and systems thinking?
- What are the critical requirements for the field to continue to evolve (e.g., the installed base necessary within academic institutions to maintain a pipeline of future practitioners)? What steps can be taken to meet these requirements? How can the field increase demand for system dynamics expertise?
- What are the logical subcommunities in system dynamics, and is it important to distinguish between them?
- As an umbrella term, does "system dynamics" do more harm than good?
- Is a common methodology shared by system dynamicists? Are methodologies shared at the subcommunity level or across model types? If not, what are the consequences to the field?
- How stable has the membership of the System Dynamics Society been over time? Who are the core members, who are the fringe players, and what effect does each group have on the field? What role do the System Dynamics Society and the *System Dynamics Review* play in the development of the field, and how might this role change?

Acknowledgments

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