THE DYNAMICS OF SYSTEM DYNAMICS

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ABSTRACT

After twenty five years of development and some notable achievements the field of System Dynamics is not as large, well-known, respected and influential as it should be based on the breadth and power of its principles and the need of industry and society for dynamic analysis of this kind. It is suggested that System Dynamics' methods be used to analyze the growth of the field and improve its development. This paper initiates the self-analysis by presenting a review of performance and a preliminary model structure for the field to encourage constructive criticism and to facilitate understanding and cooperative revitalization. The model structure may be general enough to apply to other fields as well.

INTRODUCTION

In the fall of 1956 Jay Forrester founded the Industrial Dynamics Group at the Sloan School, M.I.T. In the ensueing twenty five years many people have learned System Dynamics methods and used them to study a wide variety of systems. On the occasion of this silver anniversary it is appropriate to acknowledge our many accomplishments as well as to reflect on our present condition and future aspirations as a professional field of knowledge and practice. Perhaps, as a result of that reflection some of our weaknesses may be recognized and our research, teaching and professional practice may be revitalized, coordinated and redirected in ways that will produce an even better future.

System Dynamics is the only science-based methodology that is sufficiently logical (causal based), comprehensive, flexible and quantitative that it can serve as the basis for realistic analyses and substantial improvements of complex, dynamic, nonlinear, nonstationary, noisy human systems at the managerial levels of aggregation where the major long run behavior patterns are controlled. These are the systems (the world, countries, social agencies, industries, companies, cities, ...) and problems (inflation, escallating antagonisms and debt, oscillating profits and exchange rates, increasing hunger and crime, ...) upon which rest the survival of our civilization. Considering the vast number of critical dynamic problems now facing these systems and considering the enormous potential contribution SD could make to the solution of these problems, one would expect that after 25 years of development SD would be well-known, widely used and extensively taught. Most of the SD practitioners with whom I have talked are disappointed with our progress in these areas.

The purpose of this paper is to review our condition and to suggest procedures for identifying strategies that might improve the field and our contribution to the world community and its organizations at all levels. In order to improve the dynamic performance of the field, it is suggested that SD methods be used to perform an analysis of the growth of the field. This requires identification of performance goals, time patterns of important variables and dominant feedback loops; model building; analysis of model validity and operation; evaluation of the capabilities and attitudes of SD practitioners, clients, students and potential system participants; creative synthesis of a more effective system structure; and continuing collaborative implementation and modification of the recommendations by the field's practitioners.

This paper initiates the self-analysis process by presenting a preliminary review of goals, past performance, system structure, several possible improvement strategies to be tested, and a suggested procedure to carry out the self-study. This review will be presented at two conferences in October, 1981 to provide the greatest possible involvement of SD practitioners in the process. While the best improvement strategies are not yet known, it is certain that greater levels of commitment, direction, understanding, communication, collaboration and cooperation will be required of SD practitioners to achieve faster growth and high quality practice.

PERFORMANCE OF THE FIELD

The SD field is defined to include all worldwide accumulated SD knowledge, wisdom and information both written and mentally stored; the people who have been trained in SD methods whether or not they are now practicing SD and the SD work they have done or are doing; the client individuals and organizations who have used or are using the methods and/or have supported or are supporting their development, use or teaching; SD educational programs and students; and the combined images of the field in the mind's of potential clients, the academic community, potential students, publishing/media, and the general public. While some information about the time histories of these variables does exist, particularly at M.I.T., it is not extensive. Therefore, no definitive statement can be made about the past history or present condition. However, my perception of the time histories and present state of SD variables roughly matches the perceptions of several colleagues with whom I have talked.

This perception suggests that SD has not developed as clear and broad a base of theoretical knowledge as 25 years of work should produce or is needed to create a clear image of professional competence and to support a teaching effort which must transform normal college graduate students into capable practitioners of a difficult science-aided art. Reports of the theoretical research that has been done are widely scattered and not readily available. Careful, objective assessments of potential contributions from existing statistical and mathematical methods exist, but are not sufficient.

The applications literature is considerably broader than the theoretical; but it is inadequate in convincing, understandable, practical successes. Most applications apply either to hypothetical situations or to unimplemented studies of real systems. The nature of the field makes clear, practical successes difficult to achieve and document, but that is an obstacle we must overcome.

The number of trained practitioners seems to be smaller than it "should" be after 25 years of teaching and much smaller than it must be to do the theoretical research to develop the field's knowledge base, the teaching to increase the quantity and quality of practitioners and the analyses to study the many systems that could greatly benefit from exposure to the method. Furthermore, the quality of the work is not uniformly high. This may be due to low capability of a few analysts or special circumstances of some studies. In any case practitioner quantity and average quality both appear to need improvement.

Past and present clients and supporting organizations such as universities at which SD programs are taught, research funding organizations, industry and government do not appear to, be exceptionally enthusiastic about the field. Certainly, a few are enthusiastic, but there are only a few universities worldwide that I know about that offer SD as a field of specialization at the Ph.D. level in management, engineering, the physical or social sciences. The hundreds of universities that do not have such programs do not seem to be actively seeking skilled SD people to start advanced SD programs in their schools. The large government funding agencies in the United States such as NSF and DOD do not seem to be actively soliciting SD studies. There are some, of course, but not a number even remotely commensurate with the age of the field and the potential benefits from the use of the method. There are some SD staff groups in industry and some industrial consulting, but it is not extensive. There is some academic, industrial and government support for SD programs and projects abroad, but it also seems not to be commensurate with the promise.

Finally, the perception suggests that the SD image is not clear, widespread or very positive for people outside the field. Antagonism and/or lack of respect for the field is fairly extensive and well-known in the academic community. Since SD is not widely taught, many academicians know little about its principles. A cursory observation does not reveal the depth of knowledge and judgment required to do a proper SD study. A way must be found to communicate the true nature of the field. SD does not seem to be well-known in industry either, particularly in medium and small business, or in government, particularly at the operating levels. SD is not well-known in publishing and the news media and the general public knows virtually nothing about SD. Those who have heard of SD usually have not heard glowing reports of great successes. Our reviews typically are mixed at best.

In summary the apparent condition of SD as of mid 1981 is that it is not growing very rapidly, is not very large for its age, does not have extensive professional acceptance, has not produced many clear successes, and is not widely known or highly regarded. But it has the theoretical potential to transform the prospects for mankind. While the details of this perception vary somewhat from person to person, I have never heard anyone suggest that SD is a large, healthy, rapidly growing, well-known, widely respected field that is producing substantial numbers of high quality practitioners, important theories and successful practical results (my goals for SD). The above perceptions involve both an awareness of actual conditions and judgments about goals (what is desired). I hope that I am either misinformed about conditions or overly demanding in setting goals. But if I am correct, a great deal of study and effort is needed to improve the field's performance.

A SUGGESTED SELF-ANALYSIS

The SD methodology teaches that human systems are complex combinations of coupled feedback loops which function through time to create the fundamental patterns of variation (trends and cycles) observed in the important variables. Improved patterns are achieved by altering feedback structures in appropriate (effective and possible) ways. In any particular system the identification of effective and possible changes requires a clear understanding of the existing feedback loop structure, a thorough understanding of the human characteristics of the system's participants who will influence the changes, and a creative synthesis that discovers effective modifications within the realities of structure and human capabilities and attitudes.

I suggest that the field of System Dynamics is a human feedback system as described above which exhibits unacceptably low growth rates for its important variables. It would seem that if we are to increase the growth rates substantially, the feedback structure should be redesigned. In order to redesign the structure we must understand the shown in Figures 2-4. In a few cases variables not shown in Figure 1 are added to complete some loops. The following examples are all partial representations, so most of the variables also are influenced by variables not shown in Figures 2-4.

The knowledge base is increased by research effort (Figure 2). Research effort is influenced by practitioners' desire to do research and the availability of support for it. The existing knowledge base supports the scientific credibility of the field, influences applications quality, and helps to define the areas of insufficient knowledge. Credibility positively enhances the ability to obtain support; awareness of insufficient knowledge stimulates the desire to do research. After a perception delay applications' quality positively affects credibility. The error between desired applications success and applications quality stimulates desire to do research. The latter negative loop will serve to limit growth only if the success goal is too low or applications are highly successful.

A second area involves teaching and analysis by practitioners (Figure 3). After a time delay extra teaching effort (more SD programs) results in an increase in practitioners, some of whom teach. Total teaching effort depends on the number of practitioners and the fraction of time spend teaching. As teaching effort increases, analysis effort by the practitioners must decrease and vice versa. Increased analysis effort (given reasonable quality) leads to greater client awareness of the field and its benefits. This in turn generates greater analysis demand. Whether increased analysis demand leads to a larger or smaller analysis fraction depends on whether short or long run priorities dominate the decision. A ± sign represents the choice. There are two positive loops and one negative in this sector regardless of the sign at analysis fraction.

A last example involves education quality after a perception delay influencing students and their quality. Students influence the student/teaching effort ratio that is one input to education quality. Education quality also influences practitioner skill which contributes to applications' quality. Applications quality is one foundation for the field's total demand which partly motivates support for teaching. Student quality influences education quality and practitioners' skill which in turn positively affects education quality. The ± sign at education quality reflects the shape of the inset curve and ensures four positive and one negative loop.

PROCEDURE FOR SELF-ANALYSIS

Many positive loops exist in this complex feedback system that is worthy of our best analytic skills. The analysis should indicate why the loops are so weak. The synthesis should point to new strategies to improve quality and growth. Modeling, analysis and synthesis for a complex system are time consuming. The fall meetings should serve to identify goals, problems, some loop structure, new strategies to test, and those who want to participate in the study. Equation writing, model validation and analysis, and synthesis are tasks a group of individuals could share and communicate to the others. If enough interest exists, several groups could do independent studies to see if common conclusions emerge.

A general conference in the fall of 1982 could include a review of the analysis and discussions of new strategies. Consensus will be difficult to achieve, but if we can agree on new strategies, implementation can begin then. (1)

REFERENCES

(1) Fey, Willard, 1980, "The Philosophy of the System Dynamics Method," In 1980 Proceedings of the International Conference on Cybernetics and Society (New York, Institute of Electrical and Electronics Engineers, 1980).

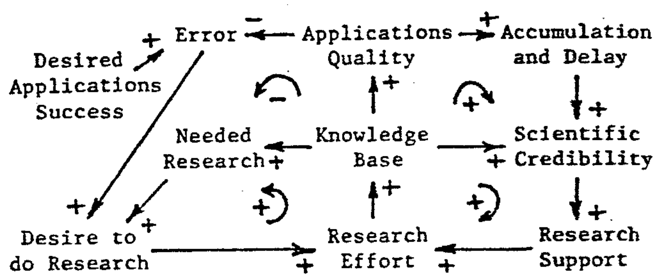

Figure 2. Some research effort loops.

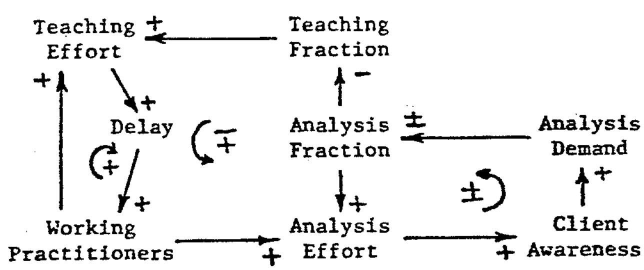

Figure 3. Some teaching effort loops.

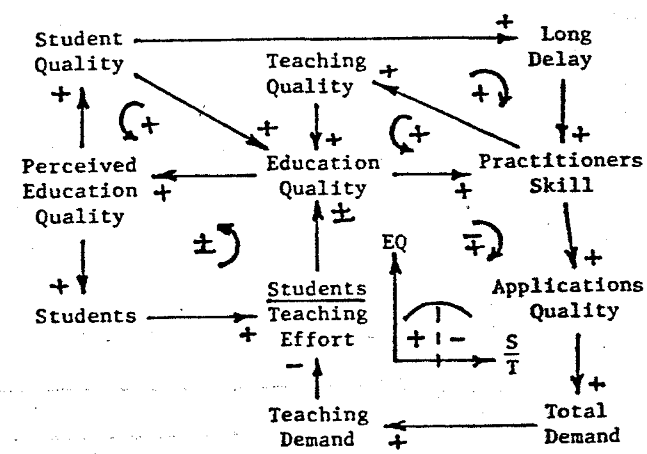

Figure 4. Some education quality loops.