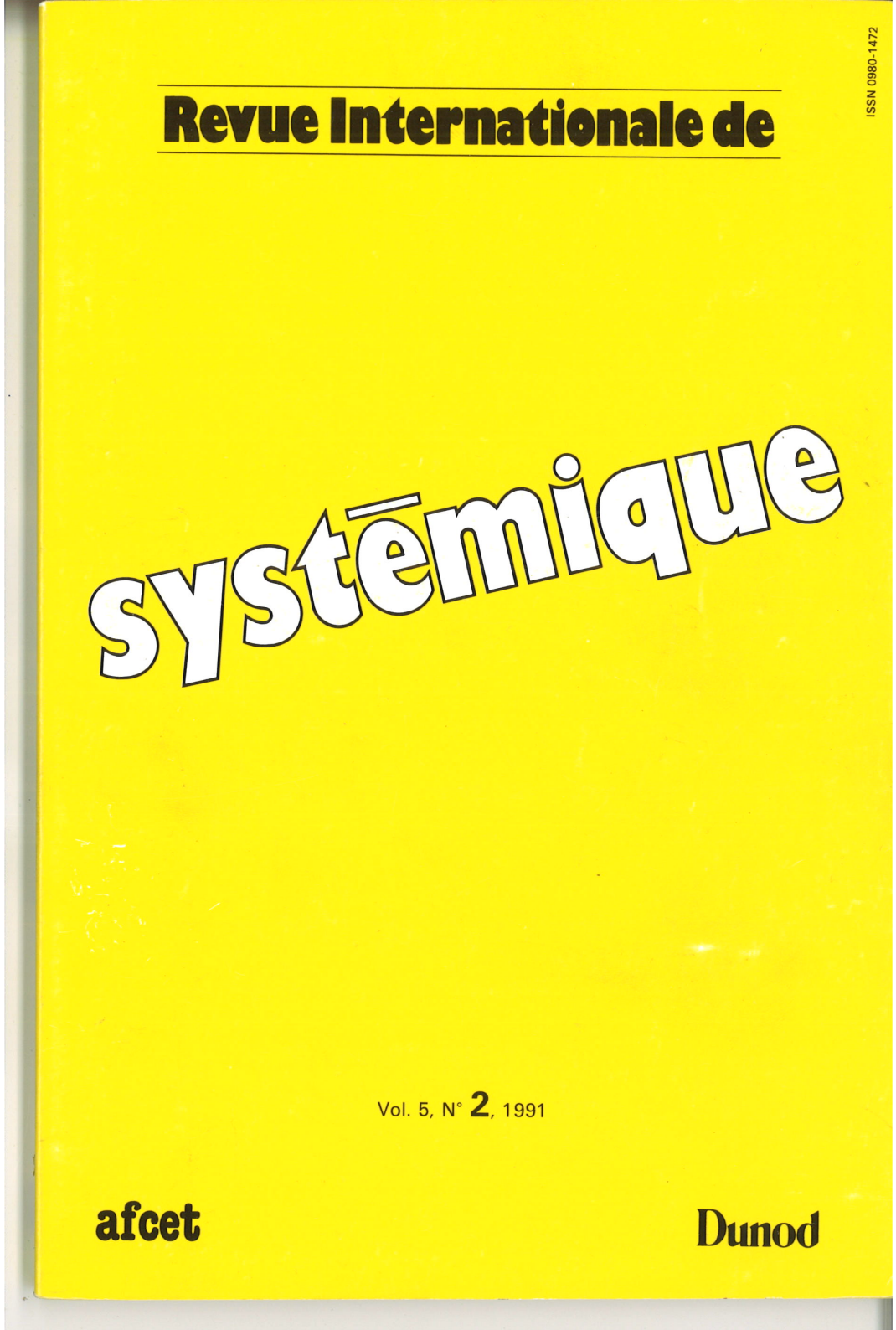

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What is to be done ?

Michel Karsky

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WHAT IS TO BE DONE?

M. KARSKY
K.B.S. [1]

Abstract
Why has System Dynamics, an approach which seemed so promising in the 60 s, not developed as expected without, however, disappearing as so many other techniques of operational research?
What is the situation today and what is the foreseable future? This paper proposes some elements for future debate and discussion.

Résumé
Pourquoi la Dynamique des Systèmes, cette approche qui paraissait si prometteuse dans les années soixante, ne s'est-elle pas développée comme on le pensait, sans toutefois disparaître comme tant d'autres techniques de recherche opérationnelle?
Qu'en est-il aujourd'hui? Quel est l'avenir envisageable? Quelques éléments de réflexion destinés à générer un débat.

The few pages which follow result from thoughts developed over the last few years, from impressions brought forth by the last System Dynamics International Congress in Stuttgart, from hopes and fears for the future on the part of a System Dynamicist who, after using and applying this science for the last fifteen years, intends to continue doing so, virtually full time, until retirement several years from now.

The Stuttgart Conference – which, as far as the organization was concerned, fulfilled all expectations – did confirm a feeling which many participants shared, even if they did not always express it openly. Namely, that our field of S.D. does not appear to be developing fast, if at all. In fact, a plenary presentation by H. Weill and K. Veit started with the question: "Why hasn't System Dynamics developed more?"

1. 340, rue Saint-Jacques, 75005 Paris.

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Signs of non-development are numerous, if of unequal value and meaning.

1. The S.D. Society is not developing fast. Although new members come in, others drop out, and I wonder whether the total due-paying membership is not somewhat stagnant.

2. The use of System Dynamics within an industrial or a business context remains irregular; new S.D. groups appear, new models are being developed: Shell in Great Britain, Renault, Aérospatiale, in France, possibly Mercedes Benz in Germany, etc., but other models have been abandoned and groups disbanded, in Norway, in the Netherlands, in Great Britain, in France, even in Italy (Montedison used S.D. some 10 to 15 years ago, a group in Bologna – TEMA – abandoned it 3 or 4 years ago).

3. Teaching System Dynamics in a University context has, on the whole, not grown for the last 10 years. To mention only a few examples: stagnant in Great Britain, decreasing in Holland (which was very active in S.D. some fifteen years ago), in Belgium, in Germany, relatively stagnant in Spain, although in a context of fast economic growth. The only exception I can think of is Italy with the appearance of regular S.D. courses given at the Boconi University in Milano.

In fact, a feeling shared by professors and lecturers in Stuttgart was that it is difficult to find enough interested students to create a full time S.D. course at a University level. Although I am not competent enough to write about the situation in the U.S., I have the impression that it is quite similar to the one in Europe. Naturally, we all have witnessed in the recent past, the interest of Chinese academia for S.D. (and apparently in India now), but I feel incapable of assessing the real long term influence on economic and political thought of such a sudden enthousiasm (the same question arises concerning our Italian friends, who were too few in Stuttgart to confirm the new development of S.D. within the Italian peninsula).

4. The number of consultants and consulting firms is not growing at a significant pace; the leading firm in this area is still Pugh-Roberts, with quite satisfactory business results but a quasi-stationary membership – the perfect example of a rich but not really growing organization. Some consulting firms seem to develop from time to time in the Boston area, often applying S.D. but without mentioning it too openly.

5. System Dynamics Software is not developing fast – with one exception: STELLA –, certainly not fast enough in our fast-moving environment:

DYNAMO (P. D. Plus) has issued only *one* operational version in nearly five years of distribution. Even if this software is now practically bug-free,

such a slow pace of development and renewal is considered too slow in our computer-led world.

DYSMAP is a University-bred (probably very high quality) software, with insufficient marketing back-up.

Other software exists or *was* offered on the market with S.D. examples as a marketing proof of their adequacy. To name a few:

CSMP (IBM)
SLAM
ACSL
Dynamine (France)
MDS (Italy)

Several of these languages do not exist any more, and the remaining are now marketed with little, if any, mention of possible S.D. application.

As I already mentioned, STELLA seems to contradict this somewhat pessimistic outlook and, benefiting from the very agressive marketing and successful sales of MACINTOSH computers, is at present selling S.D. as a "byproduct" of the software itself!

Thus, as a whole, System Dynamics, a unique and essential approach to the analysis of any phenomenon (physical, man-made device, management, economic, social, etc.) that evolves with time, seems not to be "on the move". At the Albany S.D. Congress of 1983, Jay Forrester answered the same type of statement – or question – by reminding the audience that an exponential growth curve always looks flat, like a straight line at the outset, thus surprising most observers when it takes off. We, system dynamicists, were satisfied with that idea, and hoped...

In the mean-time, vast amounts of research, development, application and sales efforts in the world have been directed for the last 10 to 15 years towards what is called *Artificial Intelligence.*

Feeling myself incompetent in this field, I shall neither describe its developments nor discuss its contents and results. Let me only state, for the purpose of future discussion and readers' reaction, that the first generation of A.I. was aimed essentially at developing the way to use "operating" rules based on the know-how of experts and on tree-type decision analysis. A new generation of A.I., however, has been emerging in the recent past, based on the awareness by some A.I. specialists that decision rules have a "causal" origin and that causality, coupled with the inevitable appearance of feedback loops, the notion of time evolution and the use of simulation techniques are essential to understand the dynamics of all evolving phenomena, the only

path, on the long term, to a rational – although not always deterministic – decision process.

This second generation of A.I. is thus developing new sub-fields called "Naive Physics", "Qualitative Physics", "Model based Reasoning", etc. Jay Forrester would probably be amused to see a drawing such as shown on

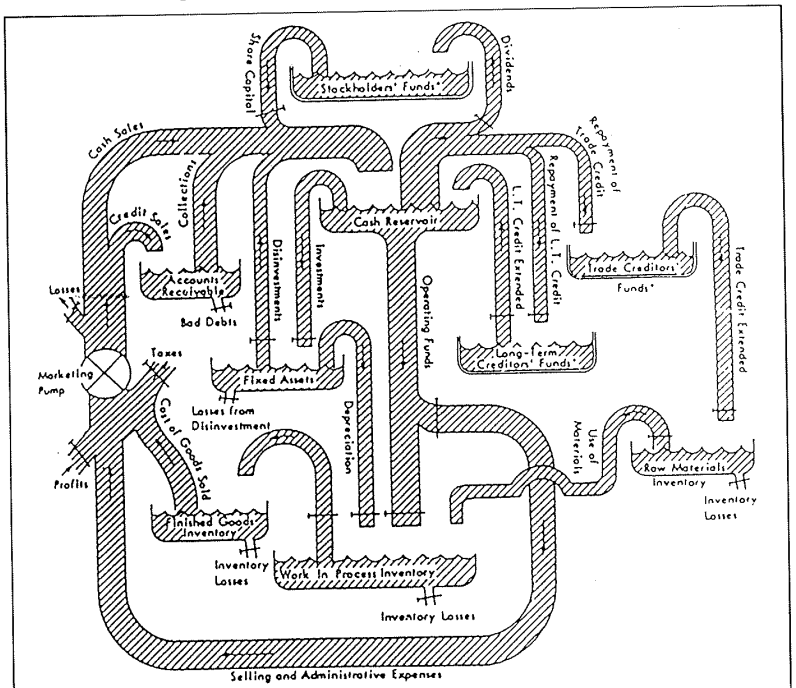


Fig. 15. Helfert's [14] dynamic funds flow model.

Figure 1.

figure 1, being printed in 1989, ([1]) or the elementary diagram of figure 2, appearing in July 1989 in a quite sophisticated System Science review ([2]). What seems to me less amusing is that in the first article no reference whatsoever is made to J. Forrester or to System Dynamics, whereas the

1. Analogical Representations of Naive Physics, Francesco Gardin and Bernard Meltzer, Artificial Intelligence 38 (1989), 139-159, *Elsevier Science* Publishers.
2. Approche Systémique appliquée à l'étude de la création d'activités nouvelles, Ferri Briquet, *Revue Internationale de Systémique*, Vol. 3, N° 1, 1989, pp. 21 à 42.

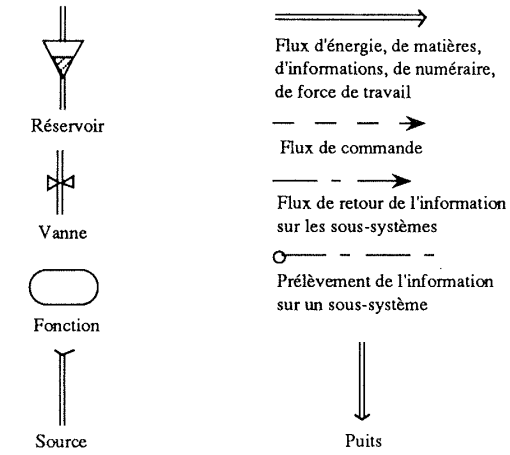


Figure 2. *Symboles de représentation des systèmes*

Le système a également un aspect fonctionnel. Ses principaux traits sont l'existence de *flux* d'énergie, d'information ou d'éléments circulant entre les réservoirs; de *vannes* contrôlant le débit des flux; de *délais* provoqués par les différentes vitesses de circulation des flux et par les diverses durées de stockage.

. . . . . .

La régulation du système est rendue possible par l'existence de boucles de rétroaction. Ces boucles combinent les effets, des réservoirs, des délais, des vannes et des flux (voir figure 3).

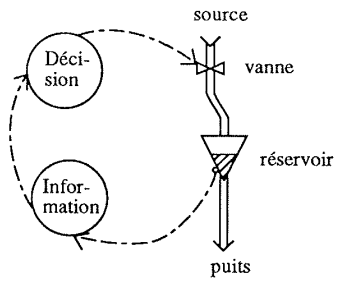


Figure 3. *Boucle de rétroaction*

Figure 2.

author of the second article, never mentioning S.D., does include "Principles of Systems" in his bibliography.

Thus it appears that the basic principles of S.D., set forth thirty years ago, namely the necessity of a causal analysis, coupled with an understanding of dynamics (whether stable, or unstable, or chaotic) through the use of feedback analysis and the use of computer simulation to help visualise possible time evolution of systems, these principles are being rediscovered by a new generation of scientists as part of a different – until now – branch of science with practically no contact with or reference to the work currently being done in System Dynamics.

However, this new branch, because of it's link to A.I., attracts not 120 specialists as in Stuttgart (a very stable number: see the participation in Paris, Brussells, Albany, Boston, Oslo, Seville, etc.), but hundreds and often even several thousand participants in their meetings, congresses, seminars, etc.

What I mean, then, is that the principles – and sometimes even the techniques – of System Dynamics are being rediscovered by others, who quite unwillingly and maybe naively ignore us but who are rapidly overtaking us through the momentum – audience, money, research efforts, ... – of A.I.

The obvious question now is: *what is to be done?* if we want to avoid being completely overtaken and pushed aside by these new and unknown to us colleagues, thus finding ourselves one day no longer at the vanguard of System Science but at its rear guard, slowly falling into oblivion and honored essentially as early but premature pioneers!

Solutions – if they exist – will obviously not come from one single proposal, but may be approached by applying simultaneously or successively several types of actions. Some ideas are listed bellow, with no pretense that any of them are potentially efficient.

1. *Change skin:* although relatively little known by most people, the name System Dynamics has a connotation of an "old" science, often linked with an "old" software (I've heard again and again S.D. being defined as "the use of Dynamo"!). Never do people think of S.D. as the future step which A.I. has yet to – and will – reach. Hence, should not the science of System Dynamics change its name? (from that point of view, the title of the Stuttgart Proceedings: *COMPUTER-BASED MANAGEMENT OF COMPLEX SYSTEMS*, is probably symptomatic!).

2. An area of Science is *marketed* – "developed" would have been the old word – through its publications, meetings and tools available for development and use. In all three areas, we are falling behind.

a) *Publication* wise, we are not very prolific, as compared to other sciences or techniques: although approximately as "old" as S.D., established and disappointing as it sometimes appears to become, Econometry has even now numerous national and international publications and congresses. And A.I., much younger than S.D., is burgeoning with reviews, books, etc.

b) These areas also progress – or defend themselves against oblivion – through numerous *seminars* and *congresses*, irrespective of possible redundancy and with no qualms as to the quality of what is being shown.

In fact, this search for "quality above all" – an MIT habit? – has maybe had consequences quite contrary to those desired; one may wonder whether this quest for top quality has not had a slowing-down effect, a discouraging constraint on some juvenile, sometimes disorderly enthusiasms which, naive and "unscientific" as they may have been, could if unhampered have constituted elements of a very needed driving force for S.D.

c) As far as *software tools* are concerned, we have shown a disconcerting lack of interest in development and adequate progress. All through the seventies, in addition to Dynamo which existed in a form which although quite revolutionary twenty years ago did not evolve drastically enough since then, many simulation languages existed, as I already mentioned, and were offered on the market with S.D. support as proof of their usefulness. Most of these softwares have disappeared or are not linked in anyone's mind with System Dynamics, a regrettable lack of marketing tools for System Dynamicists.

Apart from Dynamo, which still reigns in the S.D. world, only Stella has a new approach to both the technique of simulation and that of marketing its product. The result is outstanding: wherever used, Stella sells S.D., at least at the teaching level.

Many more ideas and proposals could and should be gathered, possibly through a series of exchanges (a "practical idea" box?). In my brief conclusion, I shall reiterate and insist on one single idea:

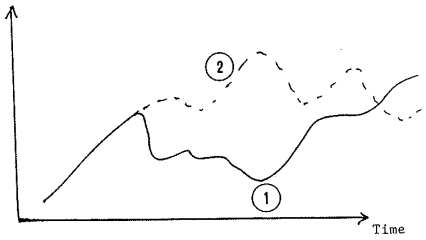
Whereas up until the early eighties System Dynamics could be considered a unique and advanced – and probably the only practically minded – branch of System Science, which could explain some lack of understanding and popularity on the part of managers, decision makers, scientists... and the general public, but allowed us to remain aloof from too much basic marketing effort, the situation is currently changing radically and rapidly: we are now in *competition* with a new, fast moving domain (a branch of Artificial Intelligence), whose pioneers and developers do not compete with us, they genuinely *ignore* us!

Whatever actions – if any – are proposed, envisaged, taken by the S.D. community, I believe we must be permanently aware of this new emerging fact, if we want to avoid being "ignored into oblivion".

Some complementary ideas

The following lines constitute an addendum to what was written a year ago and is meant to develop some of the ideas concering the present difficulties of System Dynamics, and its hopes and chances for the future.

The two curves drawn on the qualitative graph below symbolize: 1) the development of S.D., 2) the evolution of needs and/or means of System Analysis and Decision Theory.



Time moves on the horizontal axis, while the vertical axis has no quantitative meaning whatsoever, besides coincidence or divergence (needs and means of Decision Theory are no better or worse than System Dynamics, they simply coincide or they diverge!).

Thirty years ago, S.D., conceived and developed on the basis of available means, satisfied the needs of decision theory of that time. These means were essentially based on direct or indirect (digitalization) use of analogue computers, and they corresponded to a way of thinking based on differential equations, a type of mental modeling which, for the last 200 years, automatically rendered TIME an essential variable.

The success of S.D. in the sixties proves how adequate it was to satisfy the *needs* of analysts and decision makers. Why did this coincidence of needs diminish over the years?

As we all know, the developer of System Dynamics, Jay Forrester, was also the inventor of magnetic ferrite cores which allowed the tremendous development of digital computers. I suggest that it is precisely this development of digital computers which hindered the development of S.D. (Jay Forrester versus Jay Forrester!). System Dynamics is based on, and develops the notion of *understanding structural behavior*. It uses computer models, but only to facilitate the description of such behaviors, and its basic mathematical entity, although not explicitly written, is the differential equation which corresponded very much to the thinking process of many generations of scientists and engineers.

The use of computers, however, has developed new ways of thinking, essentially based on *data* and *statistics*. The present generation of scientists, engineers, economists, etc., thinks in terms of available data, of statistics, and even the new mathematics recently developed (Fractals, for example) relate to these topics and needs. Although time series and graphs can very well show time evolution of structures and variables (kinetics), these series in no way develop the same deep understanding of causal relations and corresponding dynamics, as the every day use of explicit or implicit differential equations. In fact, contrary to their elders of some 30 or 40 years ago, present time engineers, scientists, economists, although very competent in many fields, do not feel differential equations and dynamic behavior "in their guts". Hence their attitude of incomprehension vis-à-vis a science which speaks of behavior and trends more than of data, statistical analysis, etc.

My suggestion, therefore, is that the main reason for an inadequate development of S.D. in the last two decades is essentially structural and could not easily be avoided by a different attitude and set of actions of the System Dynamics community.

What about the future?

It is worth reminding ourselves that S.D. constitutes an approach to the analysis of structure dynamics, of real phenomenae which are basically "analogue" rather than "digital", and that feedback loops are bound to remain the essential cause of our poor understanding of behavior dynamics whose best representation – model – is still the differential equation.

Hence System Dynamics, under that name or another, is likely to remain a permanently needed approach to the analysis of all evolving phenomenae. And the question to be asked is not whether and when it will coincide with other decision analysis techniques, means and needs, but how to reinstate it, possibly after renovation and combination with newly emerging sciences (see some of my suggestions in the main body of the present paper), as the prime and essential approach to the analysis of all such dynamic structures which surround us, which we are part of, and to which we so often uncomprehendedly submit!