After 40 years, has System Dynamics changed?

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Abstract

Has System Dynamics changed after 40 years of fruitful practice? Although it remains clear that the System Dynamics project was a complete one from its beginnings, the need for an inquiry as to changes in the paradigm remains manifest (Fey 1981). As might be expected Forrester himself answered this question during different moments in his career (Forrester 1968a, 1968b, 1980, 1981, 1990). There have been two types of pressures that were exercised on System Dynamics, conditioning changes in the past. And both of these same pressures will also condition futures changes. One of them, of centripetal character, re-endows the practice of System Dynamics with the original style of the pioneers. The other, of centrifugal character, pushes System Dynamics practice beyond the original paradigm, to carry it to the frontiers of the social sciences. This type of practice of System Dynamics considers flow or causal diagrams and models as useful, provisional tools for achieving consensus among the negotiating parties. The parties are then viewed as clients rather than protagonists in an academic process. The first type of System Dynamics continues to have an academic style. In the second one System Dynamics is used as a consultancy tool. And while the first is rooted in tradition, the second has a mobilizing character that assures dissemination of System Dynamics outside of the academic world.

1. Introduction.

From its beginnings in the *Massachusetts Institute of Technology*'s classrooms and laboratories in the '50's, up to our times, the followers of System Dynamics can proudly look back on four hard-working decades (Forrester 1958, 1961). In view of such a fruitful production, how much, and in what way has Forrester's original idea, the use of mathematical feedback-loop models for understanding and correcting undesired social behaviour changed? It is a multiple question, because it has as many answers as there are aspects to which the question is relevant. The present work reviews the issues and from the analysis of the answers to the questions raised, it becomes obvious that System Dynamics has indeed changed.

2. Have modeling topics and modeling purposes changed?

The first real problem that caught Forrester's attention was the uncontrollable stocks of industrial inventories, that showed undesired fluctuations. The concern to maintain the system under study in a "steady state" was evident. With the appearance of *Industrial Dynamics* (1961) ends the first stage. We can attribute to this pioneering stage, as a product of *MIT*'s academic effort, a very rich and varied production of small models. Many of these models were published by Roberts (1978). In the next stage an ambitious change of denomination was to appear. The extent of the spectrum covered by the application of the new methodology developed in *MIT* forced a process of reflection and the reconstruction of the paradigm, later called *System Dynamics* (Forrester 1968).

It was hard for System Dynamics to resist the temptation of getting involved with economic problems, despite the fact it was born in a business school, the *Sloan School of Business (MIT).* Besides, what could have been more adequate than using a system dynamics approach for the definition of stabilization policies for the commodities market (Meadows 1970)? Or the national economy cycles (Mass 1975; Forrester et alii 1976)? Furthermore, in the analysis of important public affairs, why not use such a promising tool as System Dynamics? In the '70's public affairs seized the modelers' attention, forcing an ambitious change of scale. Forrester and his disciples became engaged in issues like the decadence of inner cities (Forrester 1969) or regional planning (Hamilton et alii 1969). Also problems like national fuel depletion and the transition to unconventional energy sources (Naill 1977), all of this tied to a macroeconomic model, or a world scale ecology system collapse (Meadows et alii 1974) were the main issues of those years. At that moment, the typical time scale of the models was no longer measured in decades as in *Industrial Dynamics* (1961), but in centuries. It is a characteristic of this stage of System Dynamics that models are used as a tool for prediction, in an wide sense, without the pretension of the rigor of econometric models, against which System Dynamics competed, in the academic field.

The decades of the '80's and '90's witnessed System Dynamics' return to corporate issues (Lyneis 1974). The progressive withdrawal of government from public affairs mainly provoked by the collapse of government finances in a large number of countries, had as a main consequence the lack of interest in financing the study of public problems. This forced System Dynamics to look for clients where they had initially found them during the '60's: the world of corporate management. And the return to its origins brought back the non-predictive use of the models. Then the models' purpose became a tool for strategic analysis: "By computer modeling their world, we give them a 'toy' (a representation of their real world as they understand it) with which they can 'play', i.e. with which they can experiment without having to fear the consequences" (De Geus 1992, 3).

3. Has the way of looking at society's functioning changed?

A model construction requires a social theory. The social paradigm of System Dynamics remained unchanged. It sustained the basic feedback processes like the positive reinforcing one and the negative balancing process, both driving the dynamics of the systems. These closed loops offer a powerful causal scheme that, by making use of reciprocal and contemporary causality is essential to the comprehension of social systems and the determination of effective guide-lines for their transformation and control.

Since the '70's there has been some interest in differentiating the loop, basic structure of a feedback system, from those mechanical control devices that inspired the loop conception. There is a mental model, a socially shared construction that assembles all the loops' components, joining intentions, perceptions, planning and actions. There has been, as well, a certain concern about the roots of System Dynamics. While Forrester ignored any tradition other than the Control Theory, many efforts were made during the '80's to trace the origins of System Dynamics. Even though System Dynamics was born under the aegis of Control Theory, it was possible to trace its origins, similarity and relationship to other schools of social studies, even physical science and biology. Although, strictly speaking, the System Dynamics feedback concept is inherited from Control Theory developed by *MIT*'s Professor Gordon during the '30's, and those were the ideas that impregnated the new paradigm.

Control Theory joined and synthesized findings from diverse fields such as Information Theory and Decision Theory. Paulré (1985) and Richardson (1983, 1991), as well as others, stated in well documented genealogical studies that circular causal analysis is not exclusive to System Dynamics. Many biological phenomena such as 'kinesthesia' and 'homeostasis', are mechanisms responsible for human physical and physiological stability, and were first described in the late XIX Century and beginning of the XX Century in terms of feedback structures. Most of the classical economic views have been developed using vicious circles and other lines of thought that imply the existence of compensatory mechanisms. There is also evidence pointing to the fact that explanations based on circular causality were not unknown in the Social Sciences, as is the case of the structural-functionalism school.

4. When did the pathological archetypes appear?

Atypically, the generic structure concept did not appear in a complete way from the beginning. On the contrary, it is a more or less ambiguous term that took time to be developed, and that had different meanings depending on the historical moment. While Forrester tried to identify small structure models interchangeable from one situation to another, the school later tried to identify micro-structures with their own dynamism, that once they are combined allow for the modeling of more complex systems. In the end, the conception of archetypes as pathologies— or stylized configurations of sick systems— was the dominating idea. Some pathological structures can be mentioned as examples, such as those systems that are responsible for the existence of systems unwilling to improve their performance, defeating every near-sighted policy. And then there are systems in a process of degradation; the structures describing dependant, or addicted systems where policies tend to reinforce the addiction, or make responsible external actors, while at the same time reducing their self-sufficiency. The generic structures or archetypes issue changes constantly and forms part of a modeler's interest baggage, while the literature accumulates decades of modeling experience. Thus it is that a library of causal configurations was formed, and becomes useful when someone is trying to reach a first approximation or draft of the causal structure of the system chosen to be modeled. The up-to-date list of identified archetypes constitutes a true enumeration of system pathologies.

If the literature is followed in a chronological order, a line of thought can be detected that starts with the first sketches of generic structures (Forrester 1968d), that continues with the '80's microstructures and finally ends with the '90's archetypes in detailed catalogues. Slowly, and progressively, special and almost oversimplified combinations of positive and negative loops have been identified. These combinations, however simple, have an enormous explanatory potential (Meadows 1982). Such configurations have appeared in literature under diverse names and, even though they had different meanings, in time they merged into one concept to be finally known by the popular term 'generic archetypes'. The use of the generic structures concept became more or less generalized in the '80's. Following Kiefer's suggestions, for *Innovation Associates*, Kemeny, Goodman and Senge, according to their own testimony (Senge et alii 1994, 121), identified, from some of Sterman's notes, a few minimum structures that Forrester, Donella Meadows, Goodman and other pioneers had already developed, some in the '60's and '70's. Morecroft, in turn, had considered them as mini-structures that "(...) self contained behavioral theories of the dynamic processes it illustrates. They are a way of storing knowledge and feedback structure of social and business systems" (Morecroft 1988, 314). Seen as responsible for the generation of typical behavioral patterns, later on these generic structures were left to one side and a more diffuse conceptualization started to develop. The new thinking laid the accent on the intuitive comprehension of organizations and their problems, as becomes clear in the study of the different definitions in the literature compiled by Lane and Smarts in their writings (Lane and Smart 1994). Paich, in a revision of the 'generic structure' concept, perceives its interchangeable character that allows it to go from one context to another: "dynamic feedback systems that support particular but widely applicable behavioral insights" (Paich 1985, 127). Senge put the emphasis on generic structures' universal character: "generic structures are relatively simple models of dynamic processes that recur in diverse settings and that embody important management principles" (Senge 1985, 791).

5. Was the original endogenous perspective maintained?

When Operational Research loses its appeal as a regulatory framework in social sciences for Forrester, and he refuses to conceive decision processes as open loops unaffected by the consequences of their own decisions, the history of System Dynamics starts. An open system has no awareness of its own performance. It does not make use of the available information that there is about itself. System Dynamics changes the point of view so common in the natural sciences: it is the system's particular configuration which is responsible for the system's history, and the cause of its own dynamic. The actions and information flowing within the system, affecting its state, follow a dense causal scheme. According to System Dynamics, social systems are appropriately displayed by circular causal diagrams, where today's effects are tomorrow's causes. Therefore modeled systems should have such limits that every variable genuinely affected by the system's response is not considered as exogenous. When modeling in a framework where the endogenous perspective prevails, the creation of the first structural sketch of a feedback loop model is crucial. The way Forrester (1961) created his first model, starting from a more or less complete description of the modeled system, has a lot in common with the bit by bit construction of a prototype, which is done starting from a complex scheme. Notoriously, over time, the school discovered the advantage of starting from what is simple before getting to the more complex when organizing a model structure. No matter how complex, it is always possible to simplify a model by sacrificing some details. Forrester's urban model (Forrester 1969) is, essentially, a simple structure where a negative loop is linked to a positive one, and works as the nucleus that ensures growth and stability processes in social organisms. The commodities market can be described by two inter-linked negative loops that are able to reproduce, in their interaction, the behaviors that characterize such markets (Meadows 1970). The structure of Forrester-Meadows' global models was built from the repeated use of a basic cell. This is in turn organized by a negative loop controlling a positive one (Forrester 1971b, Meadows et alii 1972, Meadows and Meadows 1973, Meadows et alii 1974).

In the '80's epistemological introspective reflection appears for the first time (Richardson 1983, Paulré 1985) and recently, researchers have been trying to isolate the different levels present in a system, until then entangled because of the lack of perspective in Forrester's models. The purely physical structure of the system must be distinguished from the psychosocial one in which the former is embodied. The two plots are regulated by a different causal logic: a mechanical logic, where each effect must be preceded by its cause, and a cybernetic logic that allows for effects to bounce back on their causes. The macroscopic organization of systems derives from the attachment of the diverse cybernetic microstructures or loops, in the particular way required by the system under study.

6. Has model diagramming changed?

System Dynamics was conceived to model social systems as though they were conservative physical systems; an approach that remains unchanged. In order to present these conservative systems a complex iconography is necessary (Forrester 1961), where all the elements present in the structure able to generate its own dynamic appear classified according to their role in the system's structure. As in Physics, System Dynamics maintains the division between the system's components: reservoir or accumulation points, technically known as state variables, and flows that, when they reach state variables, modify them. In *Principles of Systems* (1968), Forrester established synthetically the principles and rules to be satisfied when describing a system. This set of rules was in absolute accordance with the iconography developed for the systems structure description, known as 'Forrester flow-diagrams'. But such a way of describing systems, mandatory in the '60's, was too cumbersome. Because of this, causal loops diagrams replaced them.

Circular causal diagrams popularity in the '70's, was manifested in one of the first System Dynamics textbooks (Goodman 1974). This coincided with the spread of the use of System Dynamics for modeling highly aggregated systems such as urban models (Forrester 1969), or the so-called global or world models (Forrester 1971, Meadows et alii 1972, Meadows et alii 1974). The closed causal loop diagrams are the first step in the conceptualization process for a system of a controlled nature. It simply consists of words, that indicate the different parts of the system, and a network of arrows that, inter-linked, represent the direction and sign of the influence of each part on the others. The spread of the circular diagram, explained by its highly communicative potential, weakened, however, the system's conservative character. The difficulty occasioned in the first place by the excessive simplicity of the causal diagrams, and the high complexity of Forrester's stock-flow diagram, led to the creation of hybrid diagrams, a mixture of both, but closer to the causal diagrams (Richardson 1991, 154-155). Such difficulties, and the possibility in the '80's and '90's of producing structural diagrams by computer, *pari passu* the model formulation process, gave back to flow diagrams the leading role that they had had in the '60's, and had lost to causal diagramming in the '70's.

7. What happened with the formulation of models?

The art of System Dynamics modeling formulation started as a very precise, compact and complete process, and its evolution over the decades has been almost nil. The concrete formulation of a model, in terms of first order differential equations, requires a more precise distinction than the one obtained from distinguishing flows from stocks, and must appeal to integral equations, of either flows and auxiliaries, parameters and integration or graphic functions and initial equations. The equations display explicitly and quantitatively each one of the causal relations of the modeled system, *vis-à-vis* its causal structure. They form a simultaneous differential equations system, which is solved by computer simulation, that gives an individual solution to the system of equations. What Forrester wanted, from the beginning, was to model continuous processes. The discrete nature of mathematical simulation is a mere technological accident, imposed by Euler's integration method, which solves the approximation of the continuous system of differential equations. Perhaps the only innovation, almost at the beginning (Forrester 1969), was the incorporation of continuous processes by using non-linear functions as graphic functions. Such early innovation, already used in Forrester's urban model (1969), consisted in the incorporation of special relations between variables. Because of their non-linear nature some causal links are introduced in the model by graphic means. The flexibility achieved by the hypothesis' introduction, thanks to the use of graphic functions, is amazing.

The formalization scheme postulated by Forrester did not change in the '80's. Nevertheless, even though there were no changes in the formal aspect, the accumulated experience of modelers brought together as a set of elementary structures, representing different kinds of decision-making processes. By combining these microstructures any kind of policy decision could be modeled. A small group of processes is enough to characterize most types of decision policies (Richmond et alii 1987). When taken one generic process at a time, they display a characteristic pattern. But basically, apart from the combination of basic decision structures forming different types of policy rates that experience helped to put together, there were no other substantial differences from Forrester's original project.

Returning to the '70's for a moment, let us recall that a feedback system can be expressed either as a differential equations system, or as an integral equations system, as is done by Forrester in *Dynamo*. This did not pass unnoticed by the scientists involved in the polemics aroused by Forrester and Meadows in the '70's, arguing against their global models. The scientists quickly offered different versions of System Dynamics models, developed by themselves in terms of differential equations systems, in order to translate them into their own language so as to understand and, in the last resort to criticize them (Boyd 1972). This unexpected opening was very positive for System Dynamics' future development. It prepared the ground for a classical treatment of non-linearity within the model in the study of its stability. The use of simultaneous, non-linear first grade differential equations to develop dynamic systems is a very uncomfortable way to model. Nevertheless, having established such an equivalence, it is possible to take advantage of the considerable literature available either on Feedback Systems, usually found as Control Theory (Mohapatra 1980a, 1980b, Mohapatra and Sharma 1985), or on Chaos Theory. When Nobel Prize winner Prigogine developed Chaos Theory, stunning the scientific world, the influence generated was of such a magnitude that the System Dynamics Society decided, in 1988, to dedicate a whole magazine issue to System Dynamics experts writing about the different fields in System Dynamics that are related to Chaos Theory, plus other related papers (Mosekilde et alii 1988, Mosekilde and Larsen 1988, Sterman 1988). But again, no new methods for model formulation followed, and, after a while, the impact of Chaos Theory on Systems faded. Meanwhile recent software keeps on constantly improving its capabilities by adding new functions, admitting matrix equations and accepting optimization techniques.

8. Were models always validated in the same way?

The validation issue was abruptly displaced, in System Dynamics, from the neutral objectivity characteristic of the experimental sciences' scheme, to more multi-dimensional schemes. The latter, while avoiding any categorical declaration of validity, combine the traditional criteria of objectivity, with criteria of a more subjective nature, based on the recognition of the model's fidelity in its reflection of reality in the view of actors in the modeled social system (Forrester and Senge 1980, Forrester 1973). A model is considered acceptable if its actors recognize in it, bit by bit the modeled social system they belong to. Also, not only are subjective criteria of validation introduced by Forrester, but utilitarian ones as well. A model is acceptable if it serves for the purpose for which it was built.

Notwithstanding the Forresterian heterodoxy of validation criteria, the strict academic tradition also often led to a mixture of objective and subjective criteria. As the interaction between System Dynamics and other competing methodologies matured, Forrester's original subjective criteriæ tended to be complemented with other types of statistical tests. Forrester's students, in charge of modeling different national economy segments for a national model Forrester was involved with in the ’70’s, lived in an academic context that not only prevented them from ignoring any form of complementation or common language, but rather required it in order to gain credibility in the eyes of the established fellow economists at *MIT*. Theoretically, complementation was possible and desirable: while the economists were interested in the short run, system dynamicists were interested in the medium and long run. And very good models were created (Senge 1978, Sterman 1981), in connection with the national model project of Forrester, that used the statistical type of validation criteriæ. But somehow the high level of social aggregation of global models (Forrester 1971, Meadows et alii 1974) had turned the validation criteriæ into an irrelevancy and it is only when System Dynamics returned to modeling industrial organization problems, in the ’80’s and latter that this leads us inevitably back to the question of which of the oscillating extremes, the objective or the subjective, is the prevailing one in today’s System Dynamics practice. Today the focus is on subjective criteria for validation. It is clear that there is no such a thing as an immutable protocol for validation; the issue depends on the modeler’s maturity and experience. It has been noted that the use of the tests proposed by Forrester, implying extreme structural and parametric changes, plus the introduction of noises of different types and ranges, is infrequent (Robinson 1980, 262). Nowadays System Dynamics professional management consultants value most highly the models that generate more confidence, induced by clients involvement which clearly helps the client to identify himself with the model.

9. Did endogenous viewpoint for designing policies change?

Policy-making based on System Dynamics models has its own style, one quite unexpected for traditional politicians. Forrester sustained that complex systems behavior defies intuition; systems are insensitive to parameter change and, therefore, are resistant to new policies (Forrester 1969, Forrester 1970). The immediate effects of the reforms are cancelled by the system’s reactions. However, there are sensitive areas where the application of new measures is efficient. The short term policy consequences are in contradiction with the long- term ones. Forrester also noticed that social systems are burdened by problems that are usually self-inflicted and the system’s reaction to actions on them is generally unexpected; any realistic intervention in the systems requires thinking of them in an evolutionary way; the predominance of internal structures changes over time and parts of social systems are not connected in linear fashion. Social health recovery is to be obtained by destroying the responsible pathogenic structures. There are no one-shot solutions. The fallacious politicians, generators of symptomatic solutions, must be unmasked. Even though Forrester’s message, tinted by a conservative perspective, was not very popular in the ’70’s, it had great weight for many years with the experts, until System Dynamics returned to corporation consultancy. Then the pretensions and scope of suggested solutions was reduced.

A model construction process requires the reiterated exploration of different scenarios, and this leads to the model modification. Instead of guessing the future and the hypothetical scenarios, System Dynamics tries to detect and understand the system structures that create or increase perceived problems. It does this in order to seek out undermining tendencies that will tend to defeat even well-rehearsed policies: “Scenarios (internally consistent descriptions of possible futures) would be a useful input into this play process. We would normally expect a management team to come up with seven to ten options for two or three scenarios" (De Geus 1992, 4). System thinking aspires to have some control. If one believes that the problem of decadence downtown is caused by the lack of help from federal funds, then the Mayor has nothing left to do; but intense experimentation with dynamic city models generated a strong belief in the endogenous nature of social systems, which are actually masters of their own fate, good or bad. This endogenous perspective affects the construction of theory and the policy analysis. The endogenous perspective can be understood, says Richardson, as an extreme feedback loop perspective. In turn, a loop can be seen as a consequence of the effort made to identify the dynamic causes within a closed universe or set of limits. Without the existence of loops the variables would seek the cause of their variation outside the system's limits. Without the loops we should be forced to sustain an exogenous view of a dynamic system causes (Richardson 1991, 151).

10. Has the style of modeling changed?

Forrester's original scheme, sufficiently rich to cover later developments, has been basically maintained by System Dynamic experts. Reading *Industrial Dynamics* (1961) is as useful today as it was 40 years ago. But, however inspired such a book was, it was not enough. More teaching materials were required, particularly when *MIT* lost its exclusivity and System Dynamics started to spread to other academic centers in the USA and Europe. Then it became a necessity to develop more literature on how to model. It was not by chance that in one of the first System Dynamics international conferences, at Oslo (1976), experts answered the question of how to model. Scarce System Dynamics manuals, written in the '70's and the '80's, usually display in the first pages (perhaps sketch is a better word!) the procedure to be followed when building a model. In fact this discussion only makes sense once some experience in modeling has been gained. Real experience in modeling teaches the unreality of any scheme. All modeling goes back and forth from the structures' conceptualization to the formulation that specifies it (Randers 1980). The only way of learning is by doing it. Alternatively, the firsts steps in the field can be learned from a veteran expert, or by a laborious reconstruction of the process that the modeler followed, only in the cases where the model is a good one and there is a complete documentation on it.

The balance of those days shows that the most important changes in the '80's were centered on the didactic issue rather than on the main ones. Pure endogamic practice; what was the easiest way to model— to follow Forrester flow-stock diagrams, or to follow causal diagramming? System Dynamics textbooks published in these years clearly show a general preference by the modelers for a conception process based on causal diagrams. It may be so because a causal diagram is a quick substitute for a still absent model. However, the development and popularity of the archetypes reinforced this perspective. Since when they were first used, during the middle '80's, they were collected in a sort of stereotyped causal diagrams minimum catalogue. According to the pathological symptoms presented by a system, the archetypes can be used in order to adopt a specific structure as an initial sketch of the model. After *The Fifth Discipline*

(Senge 1990), a best-seller publication, the use of the archetypes spread to main management schools in the '90's.

In the '90's the discussion became more substantial. It is no longer a teaching matter. Other sciences, with other rules, enter in the game. They basically question the idea that the point of departure is the question which the model construction seeks to answer. How are we supposed to accept as a point of departure what is, in fact, the hardest thing to discover? That is: what is it that burdens the sick social system? Consistently, over the years, modelers have agreed that a model construction starts with a problem that affects some part of the social body. The identification of these problems may be evident or not, and sometimes it can be done fast. At the beginning of System Dynamics' practice, problems were established by plotting the behavior of troublesome variables over time, and such behavior in turn had to be emulated by the model. As time passed and consultancy experience was gained, the models purpose definition process become more profound and it then became obvious that the first step when constructing a model, the formulation of the issues, is also the hardest step (Senge 1989). Where as for the pioneers the problems were already defined as they saw it, nowadays common practice starts with the definition on the problem itself.

Consultancy jobs and intervention in the business world did not lead to an avoidance of discussion. While System Dynamics remained in the academic world the object of study could be chosen but, in the agitated and anxious-for-results world of management, it is hard to offer immediate results (Rufat-Latre et alii 1993). Today System Dynamics is a forum where different psychology schools offer their diverse styles and techniques in order to elicit from the actors of the sick systems a verbal account of what burdens them.

11. Where do we go from here?

The future of System Dynamics will depend on two forces that push in divergent, if not opposite, directions: one centripetal, the other centrifugal. Fortunately the academic world will keep on training future experts and generating complete models. These models will be scientifically acceptable while considering the competing modeling techniques. The 1994 Forrester Prize serves as an example; awarded by System Dynamics Award to a work for its excellency; it was received by Abdel and Madnick (1991), who for many years focused their work on improving a single model. This is a centripetal force that unites the academic community and supports the schools' scientific rigor. The other type of force, more seductive, more demanded and more media-powerful, is displayed by works such as Senge's *The Fifth Discipline* (1990). The approach tends to use dynamic models in a more rapid fashion, almost as a *non finito* product, in order to provide insights rather than directions. A more sophisticated variant of this second line is reflected in the creation of 'games' or 'micro-worlds' based on dynamic models that allow for executive training in the way pilots are trained with flight simulators (Morecroft 1988). Strategic policy-making is now a collective responsibility and a model is a tool with which to exercise such responsibility: "Note that in dealing with the future, the brain does not rely on predictions. It figures out what the human being would do under several anticipated futures... We are beginning to get a better perspective of what the end product of ‘modeling for learning’ should be ... management teams ... should be playing with their own computer-based representation of their real world to work out a number of action sequences (=options) to be taken by their business unit or company under several anticipated futures” (De Geus 1992, 4). The centrifugal direction pushes System Dynamics towards a fusion with other disciplines, particularly Social Organizations Theory and other, less rigid, systemic methodologies, less mathematically formalized, and this is clearly showed by Senge’s book, that curiously enough, also received the following year the award referred to above (Senge 1990). Both directions, the centripetal and the centrifugal are essential to contemporay System Dynamics practice, but the latter without the former exposes System Dynamics to the risk of either losing its identity or becoming trivial, or both. The harsh words of the founder regarding soft thinking techniques should not be taken lightly: “System thinking is in danger of becoming one more of those management fads that come and go” (Forrester 1994, 252).

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