Some Positive Aspects and Limits of System Dynamics in Present Conditions

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ABSTRACT

The paper points out some positive aspects as well as the limits of System dynamics based on author's own experience with practical applications of System dynamics models without aspiring to assess System dynamics methodology as a whole.

The author wants to provide some kind of system detachment and provide information of how System dynamics models help in solving complex problems, mainly with respect to gathering of new knowledge and the integration and communication of the existing one.

Questions "What knowledge can be obtained by creating the system dynamics model and its practical application to completion of the changes needed in the system" and "What is the role of the learning process with implementation of these changes in the real world?" are the starting point for the analysis of advantages and weaknesses of System dynamics.

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1. THEORETICAL FOUNDATIONS

Various physical, social and ecological subsystems, shaping our world, are inter-related in a very complex manner. We can not keep up with this level of mutual interdependence when developing our mental capabilities.

Non-systematic interferences with this system result in only seemingly working solutions, and numerous examples from practice confirm that these decisions often bring long term problems.

As a consequence they cannot solve the real causes of the problems and the problems we try to solve are becoming resistant to our solutions [19].

It is obvious that we can not consider any solution to be the correct one and it is necessary to preserve the holistic view while respecting the fact that *every approach has its contributions and limits*.

Since the *economic system is the main focus of interest* for the author, she was analyzing this topic from the following viewpoint current turbulent economic situation in post-communist countries, of which the Czech Republic' is.

The author tried to find an environment which enables us to analyze situations, find and experimentally test new solutions and immediately evaluate the effectiveness of different decisions.

She solved questions like *how to use computers for helpful simulations of entrepreneurial reality and how to contribute to "building of knowledge"*.

Econometrics[1], a very widely used simulation approach, can be used for the *simulation of economic systems*. Econometrics is based on a system of mathematical equations, the coefficients of which are based on historical data[2].

The solution of the equations is usually named as the optimal solution to the problem. The optimum is a maximum (of profit, turnover etc.) or a minimum (of costs, time).

Econometrics is a powerful tool for decision support; however the conditions when it was first used were different from today. It shows that predictions based on

[1] Econometrics is a citation as an example. This paper does not address an overview of approaches that can be used for a delineation of economic systems.

[2] Using data from the past the System dynamics proponents verify the validity of their models.

statistics are becoming less precise in the turbulent environment of today.

Methods for understanding and predicting system behavior with a model, cannot only be based on statistical data anymore, but also on an understanding of the structure influencing the system's behavior.

For the *modeling of the unstructured complex system* of today, whose behavior exhibits dramatic dynamics, it is necessary touse another tool or to combine various approaches and *integrate the econometric models in a dynamic framework* [16].

Many models allow the determining of the optimal solution for the given moment. We make a decision based on such computed solutions and our mental model. However, we cannot verify how this decision will influence the system in the future.

Every system shows dynamic properties. Each decision we make therefore has an influence on the future development of the system (both the near oand far future).

Our mind is not able to link all the relationships between individual items (moreover, often we do not know which items) nor to imagine their development in time.

The *important contribution of System dynamics* (whose methodology is founded on a systematic approach, based on a rational cause andeffect relationship), discussed in this paper, *is in helping to deeper understand dynamic probl*ems.

Systems dynamics was originally developed by Jay. W. Forrester [1][5] to help in the managerial decision-making process. *It helps to analyze complex systems and to find causal relations, delays and feedback loops* often leading to a different behavior of the system than was originally desired.

Many models ignore the existence of a feedback. However, the feedback between items of the system[3] can be a basic characteristic of complex social systems. (Items of a real system influence each other. So item 1, which caused a change to item 2, will again change, based on the change of item 2. When we make a decision, the results of that decision can influence the conditions under which the decision was made.)

In addition *many models do not deal with the issue of delay*, even though it significantly influences the stability of the system.

Another factor is the *distance of cause and effect in both time and space*. An example is the effect of globalization.

You might be a proponent or an opponent, it happens nevertheless. Its effects are related to the high measure of interrelatedness of the system's components and to delays in such relationships.

Such relationships *can be predicted and modeled only with difficulty*.

By using System dynamics for the modeling of systems *we can eliminate the linearity frequently occurring in* econometric *models*. System dynamics understands non-linearity as one of the major features of complex social systems.

The author believes that due to non-linearities, detailed and dynamic complexity[4], and the difficult determination of the target function in complex economic systems, the usual hard optimalization methods are usable only in a limited manner.

This should not belittle their potential contribution, especially in heuristic approaches.

The main premise of the System dynamics paradigm is based on the hypothesis, that even if the real world exhibits a large measure of complexity, it can be recorded in a System dynamics model [1].

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[3] The system means a purposefully defined set of components and relationships between them. As an aggregate they exhibit certain properties and behavior.

[4] The term complexity brings with it a growth in the systemic complexity of tasks being solved; from the viewpoint of both the number of components as well as the number and nature of their relationships. Dynamics and internal contradictions make using extrapolation and classical prognostic methods impossible. Besides the fact that social systems with a high measure of complexity do not have clearly defined borders and if they do, they are fuzzy.

The focus of the created System dynamics models is on a simulation that is primarily a description and experimentation.

System dynamics uses the computer simulation for a view of the question as to why the social and physical systems behave in a certain way, and to analyze the policies in complex systems. It predicts weaknesses in the policies evolving over time and helps to identify policies leading to an improvement in the situation.

System dynamics serves to grasp the knowledge we have about the particularities of the world around us.

It must be noted that System dynamics practitioners deal with the question of knowledge acquisition only, related to the understanding of the behavior of the referent system.

They do not assume that the philosophy of knowledge should be revised. *They do not deal with knowledge as a problem in itself* [21].

System dynamics focuses on modeling observed systems with the aim to help the decision-makers understand them. *The process of understanding is contained in the modeling methodology and culminates in learning from the model-building process*.

In recent years the System dynamics concept has changed because of its inclusion in a number of more general system thinking concepts and systems methods.

These attempts moved System dynamics from the hard end of the managerial disciplines to a much softer paradigm.

The original System dynamics concept in the sixties was very focused on mathematical modeling and the replication of real world behavior using clear positiviste/objective approaches.

Such a philosophical paradigm is called “hard System dynamics“. Some authors included System dynamics between functionalistic, deterministic, and hard managerial disciplines.

The question of whether or not System dynamics should be described as a hard or deterministic system was discussed many times.

The debate about hard and soft modeling: “Are models-as-transitional-objects more likely to be soft than hard?” is known. And a System dynamics web discussion is part of the hard-soft OR debate in Systems Modelling.

Premises of *System dynamics today leave their functionalistic beginnings tied to epistemology and move toward phenomenology to approaches close to interpretative and learning paradigms*.

And System dynamics use models as “transitional objects“, meaning tangible, interactive and custom-built maps and simulators for individual and team learning.

Let’s note here, that Systems theory (and cybernetics) consist of a number of research programs that were all developing in the mid 20th century. These system notions were formed in various environments for various reasons.

As a consequence the schools of thought which influenced the systems approach and main ideas of these schools developed in relative isolation and used different arguments [21].

System dynamics has many connections to various schools of thought. This author is among the supporters of the process, whereby many System dynamics protagonists in the nineties developed bridges between two strands of Systems theory: System dynamics and System thinking [15].

2. MODEL BUILDING

Even though model building is the core of System dynamics, *there is no methodology for the creation of System dynamics models*. Many sources list only recommended procedures for model building.

The basic building blocks of System dynamics models are Stock and Flow Diagrams (SFD). With Causal Loop Diagrams (CLD) they present the main starting point of dynamic systems theory.

Similar to Stock and Flow Diagrams (SFD) the Causal Loop Diagram (CLD) maps the components of the system, considering their mutual relationships. *Both these tools are used for capturing the feedback structure of the system, which is contained in our mind as a mental model*.

From the historical point of view of the development of the dynamic systems methodology, the Causal Loop

Diagram was developed earlier than the Stock and Flow Diagram.

Numerous authors, such as [14] point to the unprecise descriptive ability of CLD. This results in a missing differentiation between flow and information values in CLD.

The descriptive ability of CLD indeed hinders a precise understanding of the dynamic consequences of relationships.

The author believes that improving CLD diagrams would only inhibit their advantage of simple problem formulation in the initial stage of model building. More suitable would be combining CLD with SFD diagrams.

Three improvements would be based on the experience of the author to speed up and unify the model creation [11]. They would also allow for a more efficient education of new modelers:

- Description of typical roles and their responsibilities in model creation.
- Unification of the notation in CLD and SFD diagrams.
- Listing and updating of typical data sources.

We can further discuss another problem in model creation. A real soft system and especially a complex social system cannot be explicitly described absolutely accurately.

Unless we *set a purpose of the model in advance*, we will run a large risk of including unnecessarily large number of variables in the model.

The model would become nontransparent and would present only a “dirty“ mirror of the system it was supposed to depict. The model is not the system, it is only its depiction.

Some authors directly warn against such analysts who recommend modeling the whole firm or social system instead of the problem [19].

We need to consider not only *the purpose of the model,* but also *future users and their knowledge of the situation modelled.* The starting point for the creation of a model from available data and knowledge is defining the purpose of the model and considering its future users [17].

The methods of using the System dynamics methodology in model development are variable – given mainly by the level of the problem knowledge, users’ skills and analytical ability [10].

One of the ways is to build on dynamic problem-solving oriented models on which in a short period of time system behaviour can be simulated, changes virtually everything in the model and tests the consequences by using all the graphic and animation abilities of the given software. When I create these models I learn that the world can be understood as a complex system [11].

It also enables me to understand the changes and events that cause other changes in the world and thus reach a considerable development of system thinking. This creation leads to understanding the real situation but also limits the formalization of models and designing software as an important contribution to critical understanding.

This approach is only possible for advanced users who have the knowledge of simulation software, models and also modeling techniques.

But even people, for example university students and practicing managers, who do not have prerequisites for their own model creation, can learn some crucial principles of systems thinking and System dynamics and develop system thinking based on work with prepared models (or simulators, i.e. models with an user interface that support interactive approaches of the user to the model).

Key components of the model have to be transferred in the end to the users area of interest. Components that indicate the behavior of the model of interest to the user, set the model’s parameters and control the simulation.

We can experiment with the finished model and verify the strategies before their implementation. They enable the user to quickly change the conditions and create different situations.

3. APPLICATION OF SYSTEM DYNAMICS PRINCIPLES

3. 1. Case 1: Management problems

Application of *System dynamics principles provides the managers with a powerful tool for the securing of suitable* *strategies in company management and for the business policy market*.

It also helps to “widen the horizons“ for possible variants of solutions and to point out the key areas of decision-making while keeping a global view on the management strategy process while retaining the very important global management view.

It contributes to getting over mental barriers and to simulation of strategic thinking of a manager.

This statement can be supported by our experience from university research under “laboratory“ conditions and the pedagogical process.

Successful application in business practice in major Czech firms using models covering areas of financial management, strategy testing, risk management, development of distribution chains, project management, and implementation of Balanced Scorecard, also confirmed the above statement.

We verified the fact that when solving a specific managerial problem, mental models used for decision making are often faulty and possible future consequences of their decisions are wrongly estimated [15].

The fact is that we are only able to understand a small number of variables in mutual interaction and cannot imagine dynamic consequences.

It is well known that one advantage of System dynamics based models is the ability to enable computer models to reach higher complexity and to cover a higher amount of simultaneous calculations than mental models (even though this is sometimes questioned).

Nevertheless it is undeniable and our experience confirms that System dynamics based models and simulators can be useful for fast understandings of possibilities and for how the real system could behave.

Alternatively it may help in verifying what could perhaps happen if something in the model would change.

Despite this, *dynamic modelling and simulation methods are not very widespread*. What are the main barriers for applying SD in business and politics? How to overcome them?

The reason is its realization is considerably demanding. Also the price for the analysis, development and maintenance of the dynamic model by an external firm cannot be totally neglected. If one chooses this method, he gains a competition advantage.

There is useful to built up a network in which researches, educators, consultants, software engineers and providers, it means methodologist together with practitioners interact to share ideas and experiences for applying System dynamics in business and politics. Connecting question is could a practitioners develop a business methodology from theory or could academics proved theoretical underpinnings for a practical approach?

It is generally known that System dynamics possibilities are not only in management decision-making support.

Historically System dynamics focused on application in management areas, business policy areas, and strategy problems, up to the analysis of social and macro-economic problems and sustainable development.

This discipline can be used any time when solving problems in any time-changing physical, social or biological system.

It represents a shift from the view of the world as a set of action – reaction relationships to a mutually interconnected dynamic process.

This enables us to think about what is going on around us in a different way. We can demonstrate it on a sustainable development that becomes an important part of international and national approaches to the unified thinking about economy and environment[5].

3.2. Case 2: Sustainable development

For sustainable development many indicators were created: economic, ecological and socio-political.

[5] Literature (Forrester, 1969; Forrester 1971) analyzes the problems of exponential population growth, decreasing amounts of resources of energy and food. Models test policies that could lead to a sustainable equilibrium.

These indicators, because of their basically empirical approach, cannot provide information needed for system interference that brings long-term complex changes.

Changing the exogenous and endogenous factors in order to preserve the right trajectories of sustainable development and to understand better the processes that make it possible, it is vital for the environment managers and strategic decision makers to think dynamically and to see the problem as a whole, in its entire context.

It does not only mean to have adequate system information input, but also to change the paradigm of thinking, to be able to reveal the problems and their influence and therefore the behavior of the world [8], [12].

Even if a lot of the criticism that first *System dynamics models* limits growth was justifiable, these models *would represent a welcomed antidote to static I/O models that dominate this area of global problem research* [12].

Present models based on „breaking the bounds“ contain simplifications so their scenarios generating the changes in time and space can be understood only as instructions to possible futures, and they are not predictions in the narrow scientific sense, but it is probably our only tool for exploring the effects of our actions on future generations.

If the declarative ability of these models can be questioned, then *modelling macro-economy* in relation to ecology of one state is another situation.

It *is possible in specific dimensions to estimate the consequences of contemporary development in the area of ecology and to identify the consequences of different policies with the aim to preserve the situation on the way to sustainable development.*

The author could illustrate this on the model of the French economy with the link to carbon dioxide emissions that was successfully tested in Czech conditions. (The model is based on Systems dynamics modelling and energy input-output analysis.) [9]

At the same time we must keep in mind that *every country is a part of a global economic system*. If we want to *model* realistically sustainable development of any country, it *must be done in the global environment context*.

We should then model both globally and locally, to search for new solutions of problems in connecting space and time.

Modern approaches to sustainable development modelling using System dynamics include hierarchic linking of the global and national model and attempting to integrate time-space processes with Geographic's Information Systems.

Work with such dynamic hierarchic models requires a shift in thinking, a shift in understanding the world and the ongoing development of cognition.

This is thinking about things in the world surrounding us, not as separated, unlinked events, but as a flow of events mutually interconnected and influencing each other in time and space.

4. HOW TO GET OVER LIMITS

What to say in conclusion?

The paper wasn't in the vein: STELLA can do this and that but cannot work with matrixes, but other software such as VENSIM or POWERSIM can.

The author tries to provide a systemic overview.

By System dynamics we mean above all methodology for system understanding support and not dynamic modeling method (which incidentally goes with the traditional economic approach to the modeling of dynamic phenomena, but uses different conventions and terminology).

In this respect the focus is on the intersection of System dynamics and System thinking [6] [7].

System dynamics is not self-saving and has its limits [18].

We should mention a disputable role of the observers and the question why they observe the real world according to a certain worldview.

The other question is whether System dynamics is a problem-solving oriented approach and how can system dynamicists find a solution about something, if the 'problem' has not been clearly understood or formally defined?

Antagonists of System dynamics animadvert also on impossibility to delineate a logical framework of irrational or unexpected behaviour and advert to difficulty to describe human affairs and natural phenomena under the basis of human rationality.

Sometimes agent-based models are built instead of System dynamics modeling techniques particularly to simplify implementation of critical discrete events. And also there is increasing interest in combining the agent based and System dynamics modeling methods.

5. CONCLUSION

The author tends to believe that in Critical system thinking we should combine the strong aspects of System dynamics to what secures the system approaches. It means, for example, to accept the Multi-methodology concept, which is a method that combines and connects techniques, methods and methodologies from the same and also different paradigms of System thinking.

Such synthesizing and dialectic methodology, which arose out of a combination of two widely used system-based methodologies, from two different paradigm of system thinking – Soft systems methodology and System dynamic is Soft system dynamics methodology (SSDM).

This corresponds with the fact that recently the *System dynamics concept has converted to the general procedures of System Thinking movement and Systems Methods*. This process is very augural, and *System dynamics is one of the most promising methods to solve complex problems*.

It is not possible to discus all the questions – managing complexity, modeling, model analysis or evaluation techniques, world-macroecomic-strategy-environmental-project dynamics and so on.

Consequently the foundations, techniques, tools and applications of System dynamics will be solved by the wider System dynamics community.

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