How System Dynamics can be a help or a hindrance

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Abstract

The present paper contains a short critical description of the roles System Dynamics (SD) can play within a framework for the definition of mediated solutions to complex [environmental] problems. Its main aim is to show how SD can be both a valuable tool for the definition of shared and consensual solutions to environmental problems and a burden or a hindrance since it closes any discussion and the search of creative solutions owing to its presumed objectivity and neutrality.
The paper presents very briefly some basic concepts of SD and then discuss some key concepts (actors, experts and stakeholders) and their roles in the search for solutions to environmental problems. Then we examine with some details the various roles SD can play within the sketched framework and discuss both the various arenas where it can be used and when it acts as a help or a hindrance. The paper highlight the use of SD as both a cognitive and a meta tool in the sense that it both serves as a guide of the planning process and helps the unveiling of hidden assumptions and purposes and the diffusion of common knowledge for the solution of collective [environmental] problems.

1 Introduction

The present paper aims at examining some of the various meanings and scopes of System Dynamics (SD) within the entangled arena of human affairs where interests groups make use of formal models to dress their opinions,

interests and taking stands with the chrism of objectivity. In this framework SD can either be a help to unmask such tricks and to reveal the true positions at stake but can also be a hindrance since its "objectivity" can present a partial solution as a definite and immutable one.
The paper has a sequential structure that forces us to present the topics in a given order though they should be examined in parallel. This is true for what concerns actor, experts and stakeholders, on one hand, and problems and solutions on the other hand but is true also for the various role of SD since it is very hard and rare to find in practice pure roles but they are mixed with all the other ingredients in an often confusing patchwork.
One of the aims of this paper is indeed that of presenting SD as a meta tool to disentangle such a skein and clarify from time to time who is using SD and far what purpose.
The paper, therefore, presents the main features of SD, who can use it and why. A section on the various roles of SD follows. Then we present the various arenas where SD is played and a discussion of the hamlet's dilemma of the title to close, traditionally, with a section devoted to partial and tentative conclusions.

2 SD by the way

SD looks at reality from an holistic point of view so that reality is seen as a complex web of interrelated components that influence each other and also themselves through causal closed chains or loops. From this perspective, SD aims at defining **models** of **systems** as abstract representations of portions of reality[1].
A given portion of reality reveals itself through phenomena that can be described and that can represent problems that must be solved in someway.
Within this framework, SD tries to identify some entities that can be used to describe the phenomena of interest and their interactions through causal chains. The real explanatory power of SD resides in its passing from linear causal chains to closed chains of both positive and negative feedback loops.
In this way SD defines the so called **causal loop diagrams** (CLDs) as models of systems that are portions of reality, with all cautions of the case.

[1]The problem of defining what is meant with reality, if a reality exists or we have a plurality of realities and how can such realities be known and communicated is far beyond the scope of this paper and the possibilities of its author. For our purposes with reality we mean a subjective shared knowledge whose construction is one of the objectives of a process that uses SD as one of its tools. One of the aims of this paper is the explanation of what this, more or less exactly, means.

The next step involves the definition of the relations between our portion of reality, that we are trying to describe as a system with a model, and its external world and a characterisation of the various entities we want to use to describe the model.
For this purpose we define types for the needed variables in order to characterise conservative material flows and non conservative information flows in graphical models that mimic differential equations by using level variables as well as flow, auxiliary and constant types variables.
In this way we can define **stock-flow diagrams** (FDs) representing systems where external world exerts its influence on the model through either exogenous (i. e. constant) variables or levels' initial values as opposed to endogenous variables that form the heart of the model.
FDs can be used to model differential equations of any order that are simulated continuous time with difference equations by fixing an initial/final time and a time step.
In this way we can obtain the characteristic time trajectories of all endogenous variables, trajectories that can be compared with available data, measured on the portion of reality we are trying to model and that represent our reference patterns: if our variables succeed in reproducing such patterns within a small error we can validate the model otherwise a more or less deep revision process of the model is required up to a full redesign of the model itself and of its interactions with its outer world.

3 Actors, experts and stakeholders

Environmental problems (cf. next section) involve people at various decision levels and timings (van den Belt (2004)) both as individual and as groups. At each of these levels people involved can belong to one or more of the following (non disjoint) sets:

1. actors A,
2. experts E,
3. stakeholders S.

Actors represent people that has the political and/or economical responsibility of taking decisions in all the phases, from the design to the implementation to, maybe, monitoring and evaluation. Such decisions tend to influence the lives and interests of **stakeholders**, since they cause a change in the status quo, and are taken with support of **experts** from various fields. Among the actors there may be some of them that benefit from the "privilege" of

having the real power over the decisions to be undertaken, we call them **real actors**.
Actors are usually part of hierarchal structures so that they have natural timings and levels of involvement in a decision process. Stakeholders involvement, on the other hand, can occur at various levels and timings of a decision process (van den Belt (2004)).
Actors and stakeholders tend to form coalitions of proponents and opponents in a decision process and such coalitions involve experts as party opinionists that, in this role, may be more a hindrance than a help since they may act as unquestionable authorities that hinder the creative search of solutions from both actors and stakeholders. Experts, cf. Gordon (1994) Dalkey (1969) and Kluver et al. (2000) among the many, indeed should be involved in a neutral and possibly anonymous way so to provide the technical ground on which the search for solutions should move (cf. next section).

4 Problems and solutions

A problem is, roughly speaking, a perceived bad situation. In this sense it is either a failure of the status quo or an evolution of the status quo in a direction that is perceived as negative with respect to a desirable outcome. In both cases an alignment process is needed with more or less urgency. The [not only] key point is perception. Perception can be from either a subset of actors or a subset of stakeholders or even from a set of experts. Problems are, indeed, characterised by:

1. their level of perception,
2. their level of urgency,
3. their scope both in time and space.

Once perceived, problems must be defined more or less formally. At this point, problems claim for solutions. **Solutions** are represented by policies that guide the evolution of a system toward a desired goal. This guidance can be either top-down or bottom-up directed (Elliot et al. (2005), van den Belt (2004), Pareglio et al. (1999)). Here we have one of the many trade-offs of any decision process: quicker decision processes usually turn into longer implementation phases owing to resistances posed from stakeholders that feel to have been unduly excluded from the process whereas longer decision processes may be followed by quicker implementation phases because all stakeholders agree on the undertaken decisions and perceive them as fair and envy-free (Brams and Taylor (1996)).

As **level of perception** we denote the perception from either [some of] the actors or from [some of] the stakeholders or from both. Such types of perception do not weight the same and are guided by distinct goals and time-scales. Anyway for a problem to be perceived as such a "pain threshold" must be exceeded where such a threshold is usually problem-dependent and can be manipulated at various levels.
The **level of urgency** defines the possibility of real planning. If this level is high no participative and consensual planned solution (Butler and Rothstein (2004)) is usually possible but authoritative and top-down solutions are imposed by the **real actors**. The main issue is that, in many cases, mainly when the perception level of a problem is low, the situation is let free to evolve uncontrolled until the crisis is so near that the urgency level is raised, the perception is favoured and a last minute emergency solution is imposed.
Last but not least the **temporal or spacial scopes** contribute to the definition of the proper actors and stakeholders. It is obvious that, with respect to a problem and its potential solutions, not all stakeholders have the same benefits and suffer the same costs and, in a similar way, not all the actors can exert the same decisional power and influence.
Discarding emergency driven solutions, given a perceived problem where a planning process may be carried out usually a more or less wide succession of sets of solutions can be devised[2]. At this point all these solutions must be ranked according to the many different criteria that have been proposed till one is chosen to be implemented. This is the true hard part since both tangible and intangible goods enter into play and multiple criteria may be advocated (Vincke (1989)).
At his level the question of the feasibility of each solution is posed as well as the comparison between bad and good solutions (with respect to what? or to whom?) and between rigid and flexible solutions (Collingridge (1979), Collingridge (1983)). Both flexibility and rigidity must be seen in the costs due to an abandoning or a radical change of a solution that proves highly negative in front of commonly recognised criteria.

[2]The whole process, if we include also the monitoring and evaluation phases, spans generally over more or less long period of times ranging from some weeks to months and even years. During these periods many solutions may rise and fall many times, others may evolve and be modified and so on. We therefore speak of a succession of sets of solutions.

5 The various roles of SD

SD can play various and different roles in the interactions among actors, experts and stakeholders for both the definition of the problems and the search for solutions. The usual role is that of a faithful and neutral representation of reality in the hands of the experts that pretend, in this way, to have the only real knowledge of a problem and the only right solution so that all the others involved subjects can only approve without any dissent. Fortunately this is very seldom the case and there is a wide area of manoeuvres for the design and implementation of consensually defined solutions (Elliot et al. (2005), Butler and Rothstein (2004)). As a basic form of knowledge, in the following subsections we are going to examine such roles so to start a discussion on each of them.

5.1 SD as a normative tool

The distinction between **normative** and **descriptive** decision theory has been posed in Rapoport (1989) as a distinction between "what ought to be" in a normed world and "what it is" in the real world. We use such a distinction here between SD as a normative tool and SD from other perspectives among which we pose a descriptive role.
Sometimes SD is indeed used as a normative way to approach reality. As it is shown in books such as Roberts et al. (1983), Kirkwood (1998) and others in this stream of thinking, it is tempting to say that reality behaves as it is imposed by a model so that, obviously, if we modify some parameters of a model a necessary set of consequences will occur and reality will submissively bend. This attitude derives from hard sciences such as physics, mathematics and engineering, very apt at working with complicatedness more than with complexity, but it is out of place with regard to environmental problems that require a multidimensional and multidisciplinary approach.
This point of view may be legitimated both from the use of hydraulic metaphors of levels and flows within our models and by the fact that our models mimic differential equations.
Given that the outer world is correctly represented by a set of manageable variables whose influence can make the system behave in some predictable ways and given that these ways are governed by well posed differential equations it seems obvious that the future is strictly determined. Unfortunately (or fortunately depending on one's point of view) this is not the case within the search for solutions of environmental problems since every abstraction process through which we define the boundary of our system, the exogenous variables and the endogenous variables with their mutual ties defines

something that has no normative power.

5.2 SD as a descriptive tool

After discarding the use of SD as a normative tool we are left with it as a descriptive tool. From this point of view SD can be very valuable since it allows the experts to state their proposals both to actors and stakeholders.
This approach may suffer severe drawbacks since the degree of participation of stakeholders is usually low (van den Belt (2004)) and their timing of participation is late since all that can contribute is a feedback or a set of observations to experts' proposals that, usually, have to pass only actors' acceptance.
With all its limits in this role SD may help in the search for solutions to environmental problems since it forces the experts to explain their ideas and show how they are supposed to act on the problem under scrutiny. On the other hand it may be a hindrance since any model is posed as an objective and unmodifiable reality that must be accepted because it has been elaborated by "real experts".

5.3 SD as a prescriptive tool

Once we accept SD as a descriptive tool it is easy to see how tempting can be to use it as prescriptive tool or as a way through which the experts show how to act so that reality can be modified according to the wishes so to solve the problem under scrutiny.
The main problems with this approach can be found at various levels.

1. At the level of the model itself since acting on an SD model through a set of predefined exogenous variables so to show how a bad situation favourably modifies has nothing to do with the definition and implementation or real policies, the evaluation and monitoring of their effects and, maybe, their adjustment.

2. At the level of stakeholders that can be captured by the technicalities of the models but with a strong feeling to have been excluded from any real decision process with only a residual possibility of intervention through marginal observations.
   From this perspective SD is seen as a tool to convince the stakeholders that the solution devised by the actors with the support of a group of experts is surely the best one given a objectively fixed set of economical, technical, political and even scientific constraints.

3. At the level of the experts that usually are not a compact and homogeneous group but are often divided in cliques that, in many cases, are hard to understand if one consider that each clique founds upon objective data and theories to prescribe policies that are told destined to success.

5.4 SD as a cognitive tool

The search for solutions to environmental problems is an interplay among actors, experts and stakeholders where each category has hidden assumptions, attitudes that hide the real motivations, biases but also values and interests to protect and goals to pursue.
Within this framework SD can be used (van den Belt (2004)) so that actors, experts and stakeholders can gain a better reciprocal understanding of each other, of the problem under scrutiny and of the proposed solutions.
The availability of formal models, to be iteratively refined and modified, has also the following "beneficial" effects:

1. it forces all the parties involved at expliciting their hidden assumptions, giving up with attitudes and showing the real motivations;

2. it allows the discovery of any bias about a problem and its possible solutions;

3. it allows all the parties the expression of their goals;

4. it provides a common ground for the expression of policies and their evaluation.

For all this really happen it is necessary that actors and stakeholders are involved very early in the process and are put in the position of building their own models with the guide of experts, evaluate and validate them so that any solution can be seen as a collective undertaking. In this way maybe the decision process may last longer but the implementation phase will almost surely run smoothly (Butler and Rothstein (2004), van den Belt (2004), Elliot et al. (2005) and Kluver et al. (2000) among the many).

5.5 SD as a meta tool

Both the solution discovering process and the planning process are systems (Saaty and Kearns (1985)) and so can benefit from the use of SD that, in this case, acts as a meta tool.

In this way it may be possible a monitoring of the decision process to understand:

1. if it is effective i.e. it is getting on toward a goal;

2. if the times and agendas are respected since no process can last forever or turn in a pure waste of time owing to filibustering that, in practice, prevent the undertaking of any decision;

3. if all the parties are correctly involved and informed and none keeps hidden assets, if all participate in the process without exerting any kind of dictatorship and having the possibility to expose ideas, plans, values and goals in a respectful setting.

Similar considerations hold also for the design of monitoring and evaluation phases (that can turn in a redefinition of the problem itself and of the adopted solution, Collingridge (1983)) since such phases must be carefully designed and executed so that no false solution can be devised.

6 The various arenas

The process that may lead to the [partial] solution of environmental problems may last very long, from weeks or months up to years with the involvement of permanent administrative structures such as an **environmental forum** (Pareglio et al. (1999) and Elliot et al. (2005)).
During this hopefully creative period actors, stakeholders and experts meet many times in many places and at various levels. We can define these meetings as sessions or **arena**s since they are places where conflicts crop up and must be settled (Butler and Rothstein (2004)) so that the process can progress within a consensual framework.
In all these occasions SD can profitably play its roles of cognitive tool and meta tool but, within a consensual process (Butler and Rothstein (2004)), can be used also simply as a descriptive or prescriptive tool.
Within **technical arenas** experts can use SD as a descriptive tool to show how a problem may be faced from a particular perspective or expertise.
Within **political arenas** actors can use SD as a prescriptive tool so to explain the potential effects of a proposed policy and to get a feedback from stakeholders to such policy without disregarding the interactions among the various policies that are being planned to solve a given problem.
Within **critical arenas** stakeholders scrutinise the eventually proposed models, design their own models and evaluate the proposed policies and propose their own policies. In this case SD is used mainly as a cognitive tool.

Every category is in charge in any such types of arena but in any case the goal is the construction of a shared knowledge so that any solution can be reached at the end of a consensual process.
Last but not least, in **procedural arenas** SD can be used as a meta tool to evaluate the quality of the decision process and its effectiveness with respect to the goal and the various constraints posed by the problem under scrutiny.

7 Help or hinder, this is the question

At this point it should be clear how SD, in its various roles, does not represent a neutral tool but, rather, a way to look at problems and their potential solutions by wearing potentially distorting glasses.
SD can therefore represent both a powerful tool for reaching a consensus and shape a solution (a help) and a mind cage and a monkey trap (a hindrance).
In the former role SD is a valuable tool to help staying on tune with the problem and finding real and effective solutions. In this case experts (and SD experts too) work as a supporting team that tries to keep wishful thinking under control and maintain the decision process on route.
In the latter role it can be used to produce premature solutions, though technically correct, but that reduce creativity and hide better solutions since an objective solution has already been found out without any possibility to discover it is, on the contrary, suboptimal.
All this can happen if experts (including SD experts) play a too strong and binding role and do not resist to the temptation of devising complex and detailed models already from the first stages of the process. Even if such solutions may seem correct and be able to explain observed data they may prevent the definition of more creative and better solutions.
Unfortunately there is no general way to understand if SD is acting as a help or a hindrance and an evaluation is needed case by case and requires a careful examination of the outstanding process.
As a general rule we can say that actors tend to favour short processes and so "pre-cooked" models (and from this perspective they seem to favour SD as a hindrance) whereas experts have no objection to long professional charges and stakeholders' attitude depends on the perceived urgency of a problem but they may be trained to participate in [long] consensual processes and, therefore, to favour SD as a help.

8 Conclusions

The topic of the roles that SD can play within decision processes is too vast to be fully examined in a single paper and this paper is not an exception. What we have presented here is essentially a set of considerations that will be part of the author's PhD dissertation "Methods and Models for Environmental Conflicts Analysis and Resolution", considerations to be probed and enriched with real world cases.

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