Inductive and Deductive System Dynamics Modeling

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Abstract

The paper presents and discusses the distinction between inductive and deductive System Dynamics modeling. Findings are that the distinction between inductive and deductive modeling is helpful in appropriately setting up, conducting, and evaluating System Dynamics projects. The discussion is based on a literature review, conceptual considerations, and the insights gained from case studies, both within business and academia. Implications are different processes, different potential outcomes, and different possibilities for implementation for the two modeling approaches. The value of the paper lies in a new perspective on the most relevant question, why some System Dynamics projects thrive while others fail.

Keywords: methodology, induction, deduction, modeling projects, business cases

The purpose of this paper is to present and discuss two approaches to System Dynamics model building: inductive and deductive modeling. We will argue that inductive model building is appropriate for solving real world (business) problems; deductive modeling is adequate for the academic treatment of organizational phenomena. From this distinction, some implications result concerning the process of model building, the nature of simulation results to be expected, and the validity of conclusions to be drawn from the modeling endeavor. This work was motivated by the question, why some System Dynamics projects succeeded and others failed, meaning that no organizational impact could be achieved. We observed that a mixture of inductive and deductive modeling leads to inferior outcomes of modeling projects. On the one hand, quite often, System Dynamics projects in business are too “academic” in a sense that they rely too heavily on the rational insights and intrinsic motivation of participants and expect a more-or-less power-free and open discussion. On the other hand, scientific modeling projects are usually not appropriately described by applying common System Dynamics modeling procedures that rely on structured and phased project management concepts.

The paper is divided in three sections. First, we elaborate the problem setting of the paper, as briefly indicated in the preceding paragraph. In the second section, the distinction that we propose between inductive and deductive modeling projects is presented in detail. In the last section, we discuss advantages and implications of this distinction for conducting System Dynamics projects.

Modeling a problem versus modeling a system: revisited

It is one of the widely established rules for System Dynamics projects that they should aim at solving a specific problem. In other words: "model a problem, not a system!". This guideline appears to be useful and sensible when we take into account that System Dynamics over decades has focused on being an "applied science" (Graham 2002). In line with Graham's observation, the evolution of the "model a problem" guideline can be seen in the relevant System Dynamics literature. While Forrester originally speaks in rather general terms about focusing on goals and questions to be answered (1961, 44, 60), he later on restricts the focus of System Dynamics studies to occurrences of "undesirable system behavior" (1994, 245), although still naming the first phase of a modeling project "Describe the system [!]". Subsequent authors—most prominently Sterman (2000, ch. 3), Coyle (1996, ch. 1), Roberts et al. (1983, ch. 1), Richardson/Pugh (1981, ch. 1&2)—explicitly concentrate on "problem articulation" or "problem definition" as a first step in modeling. Arguably, the tendency to fixate on problems as origins of System Dynamics projects was amplified by the wish to establish System Dynamics as a tool for managerial decision-making. Therefore, one might call this pragmatic approach to System Dynamics modeling *inductive* modeling because the solution to a specific problem is sought as well as a specific situation serves as the basis for the model. Later in the process, insights gained in the project might be generalized but the primary focus is on solving a specific problem.

Indeed, if one wants to use System Dynamics in a managerial context, focusing on actual problems is beneficial out of at least two reasons:

1. Executives experience a high level of time pressure and complexity within the working environment (Lissack, 1999; Forrester, 1980). An approach that concentrates on something which is seemingly not a pressing problem makes the method appear ineffective and would render System Dynamics

inapplicable. Thus, problem concentration is a crucial factor in “selling” System Dynamics to business people.

2. In the past, approaches to build total models of enterprises have failed (Sterman, 2000, ch. 3). Therefore, having the entire company condensed into a model in order to run simulations whenever problems occur is not an option. The missing problem focus hinders to define reasonable boundaries of the model; it lacks the filter to determine, which factors must be included in the model, which can and should be neglected.

The System Dynamics literature reports on many successful applications of the inductive way to start modeling projects (see, for instance, in Richardson 1996; Morecroft and Sterman 1994; Roberts 1978). In this manner, System Dynamics has demonstrated its usefulness in tackling and solving difficult managerial issues. The danger, when not following the “model a problem, not a system” rule, are overly complex, or trivial, or just messy models that result in no or not valid insights from the modeling and simulation process—not to speak of missing recommendations for the systems’ stabilization or improvement.

However, there is also a downside to the inductive approach, which becomes apparent in Graham’s statement that in System Dynamics “there is a traditional of ruthless rejection of many of the trappings of scientific method if there is danger of conflict with practical utility” (Graham 2002, 4). Although there are many areas of usage where the inductive approach to modeling seems to be the only applicable one, there are other areas where it might not be necessary or useful to have an actual and real problem at hand to start modeling, rather an interesting phenomenon would be sufficient. We call this *deductive* System Dynamics modeling; the resulting models we call “conceptual simulation models” to indicate that they are often not fully calibrated and validated against empirical data.[1] For instance, if we shift the focus of attention from supporting managerial decision making to understanding organizational structure and behavior there is no actual real problem to start with a System Dynamics study (if the pathological explanation is excluded that our not-understanding of the organization’s behavior constitutes an abstract problem). Nevertheless, virtually nobody will disagree with the statement that organizational behavior is a complex and dynamic phenomenon and, thus, the System Dynamics method might be suitable to investigate it in general.

Besides different starting points (real-world problems versus academically interesting managerial phenomena), the inductive and the deductive approach to System Dynamics modeling also differ in the last step of modeling projects. In inductive modeling, emphasis is put on the implementation of improved policies that were derived from the modeling project. When tackling a real organizational problem this makes a lot of sense. However, when our interest in modeling is more academic, neither an implementation of insights is—at least in many cases—easy to accomplish nor intended. Firstly, to gain policies that can be implemented is hardly possible because the model is deliberately generalized from specific cases, which does only rarely permit to make valid statements about the design of policies for a special situation. This poses the threat of using superficially designed policies that might lead to unintended results and unforeseen side effects. Secondly, policies for improvement are not intended because there was simply no problematic situation to be improved identified in the beginning of the modeling project. Modeling that follows the deductive approach usually is more focused on descriptions of systems than on prescriptions for improvement. The best it can provide is the identification of factors, linkages and policy formulations that might be interesting to look at if a real system needs to be changed.

The reader should note that we are aware of the helpfulness of inductive modeling for securing tight model boundaries. But of course, as the inductive also the deductive approach does not intend to model systems without having a clear perspective from which it should be modeled: only the consideration of a model's purpose allows making decisions about breath and depth of a model. Nevertheless, we ask ourselves why specific problems are widely taken for granted as the sole origin of modeling projects—and about how and why this is communicated to the "outside world". In our understanding, inductive modeling narrows down too much the applicability of System Dynamics to specific real-world issues that can be solved or at least improved by designing better policies with the help of System Dynamics. As a result, System Dynamics is seen as a (consultancy) method, not as a structural theory to represent social systems (Lane 2001a, 2001b). In this way, it misses some of its potential, for instance in academic discussions.

Nevertheless, some of the best-known System Dynamics models seem extremely helpful in identifying real-world issues and suggesting robust policies as remedies for these issues, even though these models are presented as general representations of phenomena.[2] Examples are Repenning and Sterman (2001), Rudolph and Repenning 2002 and Sastry 1997, which derive valuable insights from what appears to be deductive System Dynamics modeling. In these papers, the methodological approach of using a conceptual System Dynamics model is discussed. However, to our knowledge there is only one cluster of papers that explicitly discusses the topic if and in what form conceptual models might be different to models resulting from projects following an inductive approach, i.e. models which concentrate on solving a real-world problem (Wittenberg 1992; Barlas 1992; Radzicki 1992; Sterman 1992).

Similar to what has been said concerning the inductive approach, the occurrence of the deductive approach in some studies is connected to the question of the target audience. The discourse in some scientific communities, for instance in organization science, is more abstract and theoretical than in the business literature. This explains why even proponents of the inductive approach follow the deductive approach when it comes to publishing in certain scientific journals. We want to emphasize that we do not object to this kind of “pragmatism” because it is obviously useful to target an endeavor to the relevant clients/audience. The point we want to make is that—to our understanding—the second form of System Dynamics modeling, the deductive approach, is hardly recognized and accepted within wide parts of the field, which is symbolized by the inappropriateness of phased System Dynamics modeling procedures for deductive modeling. Usually, modeling following the deductive approach simply requires a less-structured approach, which even could have negative effects on the creativity and innovativeness of the model.

The confusion of inductive and deductive modeling leads to paradox situations: models are built following the inductive approach—with high demands concerning the applicability of the results—when the best that can be hoped for are some general insights into system’s behavior. However, the classical modeling process procedures are not suited to represent deductive modeling because it regularly does not start with a concrete problem, because usually it is not well structured, and because often it is not embedded in a “real” organizational setting. Of course, the other path exists, too: models are built as general representations of social phenomena (i.e. in a deductive fashion) when concrete problem solutions are needed. In this way, modeling projects become overly “academic”, i.e. resulting models are suitable to derive intellectually interesting insights, but not concrete problem solutions and the modeling project is not designed as an organizational intervention (Snabe and Größler, 2006; Snabe et al., 2006), frequently leading to no or just limited impact (Größler, 2007).

Characteristics of inductive vs. deductive System Dynamics modeling

As a summary from the preceding section, the deductive and the inductive approach differ in the purpose of the modeling endeavor: the inductive approach focuses on problem solution, the deductive approach on understanding. Further, inductive and deductive modeling differs regarding the concreteness and direct applicability of results from the modeling and simulation project: the inductive approach yields concrete recommendations for policy changes; the deductive approach identifies sensitive policies and parameters without aiming at suggesting detailed changes. Despite these differences, there are many similarities between the two approaches. Without going into too much detail at this point, we can state that both approaches follow similar rules concerning model boundary, guidelines for quantification (in particular, quantification of soft factors), knowledge elicitation, and the value and way of using simulations to generate the time behavior of a model.

Table 1 presents an overview of the characteristics between inductive and deductive System Dynamics modeling. Some of the characteristics have already been discussed in the previous section, in particular, the different starting points: usually, inductive modeling starts with concrete problems and deductive modeling with an abstract demand for knowledge. However, as with most dichotomies, differences between the two approaches are artificially emphasized, while in reality there are, of course, "different shades of grey".

	Inductive	**Deductive**
"Nick name"	Pragmatic	Academic
Object of investigation	Problem	Phenomenon
Starting points	Concrete, practical problems	Organizational phenomena: missing knowledge/transfer of knowledge/curiosity as abstract problems
Motivation	Problem exists, solution is wanted, method only of secondary importance	Method is believed to be powerful, identification of corresponding phenomena, sometimes offer solutions
Initial phases in modeling process	Project set-up, problem definition, stakeholder management, dynamic hypotheses	Much more artificial: dynamic hypotheses, initial model
Target group	Stakeholders, problem owners in organizations	Academia, managers with general interest
Typical size of models	Big, much detail complexity	Small (archetypes, generic structures, modules)
Parameterization	Full, empirically based	Many assumptions, introspection by modelers, literature

Primary validation	Behavior (based on structure)	Structure (in combination with behavior)
Type of modeling	Often participative, Group Model Building	Mostly expert modeling
Basis of modeling	Focused interviews, observations, discussions, etc. and deductive models	Empirical experiences and inductive models, sometimes accumulated over a long time-span
Final judgment about quality	Business applicability: is problem solved/mitigated?	Academic impact: is science advanced?
Modeling process as…	Organizational intervention (policy improvements)	Individual/team process of knowledge generation (understanding)
Publication as…	Case study (maybe with the aim of theory generation)	(Minor/Mid-range Content-) Theory (a set of hypotheses)
Duration of modeling process…	Usually weeks, maybe months	From days to decades
Quantitative/qualitative modeling	Sometimes only qualitative when resources are tight or outcomes are sufficient	Often quantitative because of additional insights to be gained and because it is the classical way
Role of empirical research	Model is directly built based on empirical data of specific situation	Model stems partially from empirical experiences, partially parameterized with empirical data
Possible relation to theory	Exploration	Confirmation
Examples	Pugh-Roberts airline model (Lyneis, 1999)	Cycles in the sky (Liehr et al., 2001)
	Forrester's production distribution model (Forrester, 1961)	Beer game like 4-tier supply chain model to demonstrate/explain bullwhip effect (Milling and Größler, 2001)

Table 1: Overview of differences between inductive and deductive modeling

[In the final paper, the characteristics will be discussed in more detail.]

Implications for conducting System Dynamics projects

What are the implications of distinguishing between inductive and deductive modeling for System Dynamics projects? In our view, any modeling project can benefit from the clear identification of the approach to be taken and the consideration of characteristics typical for this approach (as laid down in Table 1). Simultaneously, we assume that the (often implicit) adoption of the wrong approach (or of some characteristics of it) leads to low impact or even useless modeling endeavors (Größler, 2007).

When conducting a System Dynamics project in companies, usually inductive modeling is what is wanted: a specific problem needs to be solved, based on a detailed model, which is built on empirical data as precise as possible. The outcome of such projects should be improved policies. When following this approach to modeling, one should be aware that—although phased modeling procedures from standard System Dynamics text books do apply—these need to be extended by more comprehensive organizational intervention techniques and architectures (Snabe and Größler, 2006; Zock, 2004). This necessity originates in the insight formulated from many scholars in the field that often the modeling process is more important than the resulting model (Lane, 1995; Sterman, 1988; Forrester, 1985).

In contrast, many modeling projects in academia follow a deductive approach: the starting points are (sometimes rather abstract) organizational phenomena, models are usually as parsimonious as possible, and are based on literature sources and on best-guesses from the modelers. The result of this kind of modeling is improved knowledge that is embedded in the model and the simulation experiments that can be conducted with it. When taking the deductive modeling approach, phased project concepts are usually inappropriate because—much more than in the inductive case—modeling is an art and an intellectual act that is based on the creativity of the modeler. Furthermore, the embedding of the modeling project into an intervention architecture is not necessary.

In summary, with the distinction between inductive and deductive modeling projects as proposed in this paper, wrong expectations can be avoided. Additionally, critical elements of the modeling process are clarified so that “easy” mistakes can be prevented.

[In the final paper, these implications will be discussed based on a case study]

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Notes

1. There is no discrimination intended by using the terms *inductive/pragmatic* vs. *deductive/academic* for the two approaches to System Dynamics modeling. We acknowledge the importance of both directions and try to accumulate expertise in the two ways of modeling.
2. This resembles Kurt Lewin's famous saying that "noting is so practical as a good theory".