Table of Contents

Go Back

Do models evolve?

Abstract

This paper starts with the idea that learning in the context of system dynamics modeling does not only happen during the modeling process, but also goes on between the iterations of the inquiry process modeling is part of. The notion of model version is introduced and it is suggested that the differences between successive versions of a model represent what has been learned in the inquiry process. A set of structural elements with a set of indicators are proposed in order to capture theses differences and give them meaning in terms of the learning process.

Keywords: inquiry, learning, modeling, knowledge

Introduction

System dynamics modeling is presented as a means of learning. It is a chance to learn about a system (improve understanding) before intervening in it. As such, even though a model's usefulness may be limited to the scope of its purpose, or "all models are wrong" (Sterman, 2002), modelers still need their work to be "right" (or trustworthy) in order to publish it, for instance.

However, what happens after a model has been accepted as valid? If the "all models are wrong" message addressed the limited validity of models in the space of multiple purposes, it hardly concerned itself with what happens in the longer run: it is like once a model's validity for a given purpose is agreed upon, this will not change any more. But trust in a model at one given moment does not mean the represented knowledge cannot be improved on: implementation has a potential of showing further weak points in a model or its underlying assumptions, be it because some aspect had not been considered or because the world changes over time.

This paper argues that inquiry can and should go beyond the "acceptation" of a model, which is certainly compatible with the view that modeling is part of a larger, encompassing inquiry process (Sterman, 2000, p. 34).

The first section elaborates this idea by reviewing influential models of inquiry. The second section introduces the distinction between a model as a dynamic stream of evolving understanding and a model as a specific expression of an understanding at one point in time. It proposes that the differences between the successive versions of a model can be interpreted as the trace of learning that is going on at the general level.

SD modeling between inquiry and science

Sterman (2000, p.34) and others (for example Morecroft and Sterman, 1994) present system dynamics modeling as a means for overcoming human limitations in the learning process. By making mental models explicit and confronting them with empirical test based on simulation, the very mental models evolve (improve) and therefore, decisions improve. As a consequence, there are less side effects and policy resistance. This is why system dynamics is understood to be complementary with double-loop learning. Thus SD stands in the tradition of inquiry as developed by Peirce (1877), Dewey (1938, 1991), Lewin (1951), Kolb (1984) and Argyris and Schön (1996) and others (Schaffernicht, 1999, 2001, 2002).

Inquiry proceeds in cycles of more or less 4 phases: first, something alerting is detected, arousing doubt; then, it has to be established what the problem or the situation is. Afterwards, reflection and search of available knowledge are put to work in order to generate a (still hypothetical) solution. Finally, the solution is enacted and either the results confirm the elaborated idea (and doubt is settled) or for some reason the supposed solution does not work out. (Maybe the expected effects did not show, or unexpected effects were observed.) In this case, doubt is not settled, or new doubts arise, and the process goes into the next iteration.

System dynamics modeling can be assimilated with the second and third phase of the inquiry cycle: clearly it makes modelers learn about what the problem is and how to behave in order to overcome it. Sterman (2000, p. 45) shows this kind of learning using different scales of black/gray: in the models presented in the book, the initial model is printed in black, and components added due to insights are inserted in gray. Thus, the reader has an immediate view of what has been learned during the modeling.

Subsequently, the new elements lead to new policies and actions, which closes the inquiry iteration. However, can we be sure that doubt has been settled? Do models evolve inside the inquiry process, as it goes through later iterations? Or can a model be expected to be definitive?

If the model was a scientific one, in the positivistic sense, once it had been accepted it would not change, because doubt would have been settled definitely. However, system dynamics is a pragmatic discipline, and the very image of models being part of a double-loop learning process suggests that models are subject to critique, error and improvement after the implementation of their suggestions.

Model evolution as traces of learning

If a system dynamics model is the expression of mental models and these are one kind of knowledge, and if learning means that knowledge changes, then changes in system dynamics models would indicate and imply learning. In this case, we may say that the mental models as a living body of knowledge are expressed by a sequence of system dynamics models, and design a method for comparing these models in order to infer learning steps.

Before being able to compare two successive models, we have to define the component architecture of SD models. It is commonly thought that SDM are built from levels, flows and auxiliaries. However, there are identifiable and meaningful structures in between the atomic level and the "model":

- a collection of levels may be bound together by flows, representing a system of states of a *resource*;
- a collection of components may constitute one *sector*;
- a collection of components may constitute a *decision*;
- a collection of components may constitute a closed *loop* (any single component may be on more that one loop.

Several things may happen to each of theses structures. When looking at two successive versions of a model M - M_{t-1} and M_t - the following indicators would tell something interesting:

Structure	**Event**		
	I: Insertion	*M: Modification*	*D: Deletion*
R: Resource	number of new Resources in M_t, divided by the total number of Resources in M_t	number of Resources that staid in the model but with a modified set of accumulators divided by the total number of Resources in M_t	number of Resources deleted from M_{t-1}, divided by the total number of Resources in M_{t-1}
S: Sector	number of new Sectors in M_t, divided by the total number of Sectors in M_t	number of Sectors that staid in the model but with a modified set of elements, divided by the total number of Sectors in M_t	number of Sectors deleted from M_{t-1}, divided by the total number of Sectors in M_{t-1}
D: Decision	number of new Decisions in M_t, divided by the total number of Decisions in M_t	number of Decisions that staid in the model but with a modified set of elements divided by the total number of Decisions in M_t	number of Decisions deleted from M_{t-1}, divided by the total number of Decisions in M_{t-1}
L: Loop	number of new Loops in M_t, divided by the total number of Loops in M_t.	number of Loops that staid in the model but with a modified set of elements, divided by the total number of Loops in M_t	number of Loops deleted from M_{t-1}, divided by the total number of Loops in M_{t-1}

These indicators can be used to represent how much a model changes from one version to the following one. We may distinguish between four manifestations of learning:

- *Growth*: the insertion indicators (RI, SI, DI and LI) have high values;
- *Correction*: the modification indicators (RM SM, DM and LM) have high values;
- *Shrink*: the deletion indicators (RD SD, DD and LD) have high values;
- *Confirmation*: all indicators have low values.

For sure, there may be more than two versions in the history of one model, and so it becomes interesting to monitor the evolution of the indicators over the successive version changes: if they tend downwards, we would be tempted to say that this model stabilizes, in other words: the encompassing inquiry process has brought about a series of learning steps that generated a durable model, a particular kind of theory-in-action we might say. However, the absence of such convergence would not prove the absence of learning, since the modeled system is not guaranteed to say without changes over time. We may call these two profiles of the learning process:

- *Convergent*: the indicators tend towards lower values, which is indicated by Shrink or Correction, each followed by Confirmation;
- *Erratic*: the indicators display sequences which include Growth and Correction; the do not show Confirmation.

Sadly, the author is not in possession of such a series of model versions: for lack of personal trajectory in the field and also for lack of such series available in the System Dynamics Review and the standard textbooks, it is not possible to present a real example in this paper.

However, we can refer to the model represented in the "automobile leasing strategy" case of the Business Dynamics book (Sterman, 2000, p. 45).

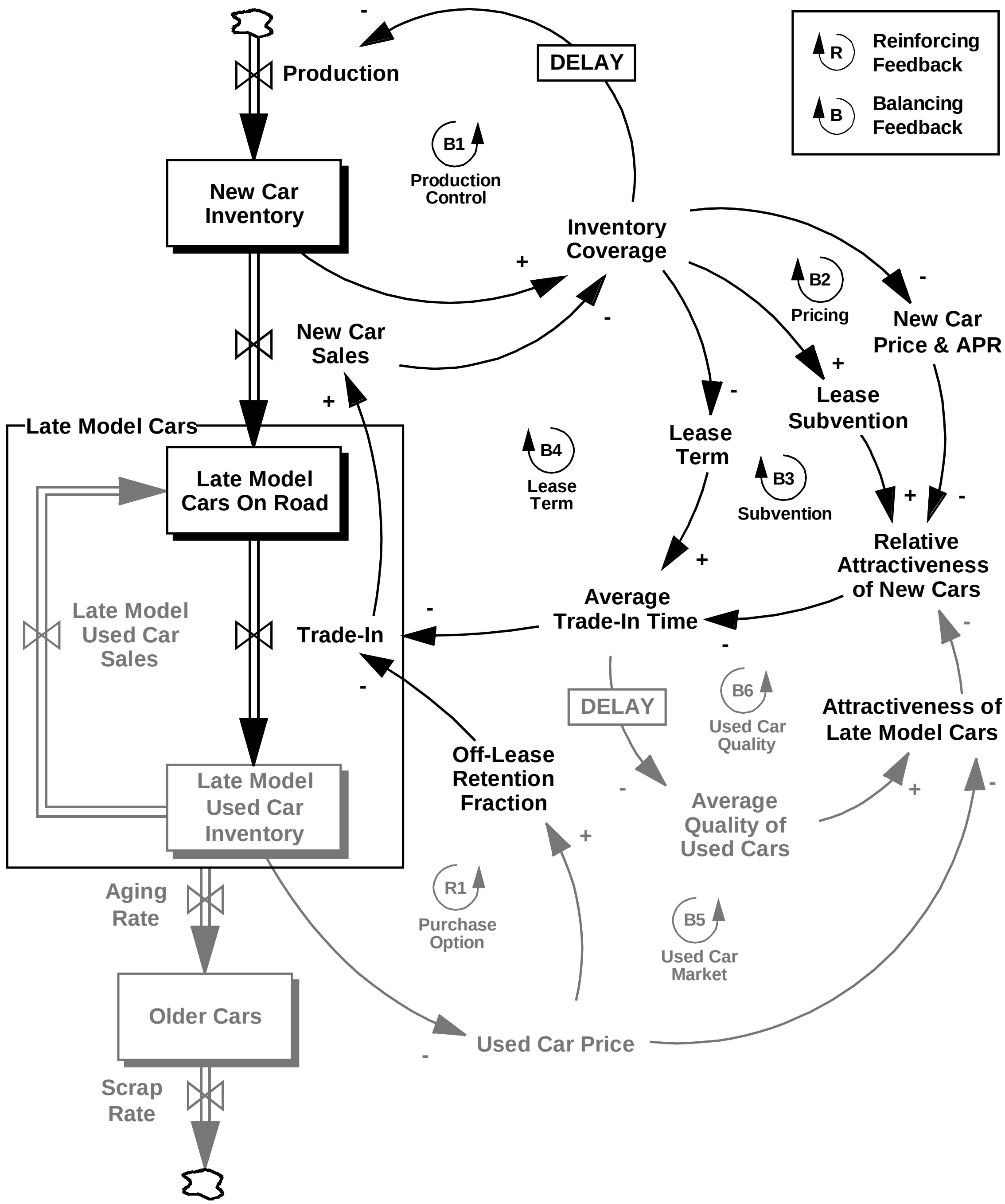

Fig. 1 - the automobile leasing strategy model (Sterman, 2000)

We begin by synthesizing the model's structure in its initial and later version:

Structure	**Model versions**	
	M_1	M_2
Resources	1 (cars, with 2 accumulators)	1 (cars, with 4 accumulators)
Sectors	1	1
Decisions	2 (new car sales, trade-in)	4 (new car sales, trade-in, late model used car sales, scrap rate)
Loops	4 (production control, pricing, subvention, lease term)	7 (production control, pricing, subvention, lease term, used car quality, used car market, purchase option)

With these descriptions and the definitions of the respective indicators, the following values are determined:

Structure	Event		
	Insertion	Modification	Deletion
Resource	RI_2=0%	*RM_2=100%*	RD_2=0%
Sector	SI_2=0%	*SM_2=100%*	SD_2=0%
Decision	*DI_2=50%*	DM_2=0%	DD_2=0%
Loop	*LI_2=43%*	LM_2=0%	LD_2=0%

These numbers cannot tell what the meanings of the model changes are; however, *Growth* and *Correction* do tell that the model has grown notably. Since there are only two versions available in the textbook example, we cannot know if there occurred *Convergence*. Further monitoring of the changes from version to version may use the following form:

Indicator	**Version**			
	1	*2*	*3*	*4*
RI				
RM				
RD				
SI				
SM				
SD				
DI				
DM				
DD				
LI				
LM				
LD				

There are reasons to believe that in some domains, system dynamics models are developed and used over longer periods of time, for instance in the periodic evaluation of information systems (Wolstenholme, 1993). It also seems reasonable to assume that these models are rather large. In these cases, being able to monitor the evolution of the model is the opportunity to visualize the learning that is going on in the inquiry loop.

Since this enables to detect if the modeling approach works (Convergence) one may conjecture that this a double-loop instance and a chance to become proactive and manage the inquiry process.

Conclusion

This paper set out stating that learning in the context of system dynamics modeling does not only happen during the modeling process, but also goes on between the iterations of the inquiry process modeling is part of. It was argued that even though each modeling project concludes with a declaration of validity for the space of the agreed purpose of the model, this cannot warrant that validity resists time. By consequence, doubts may persist or re-appear, and inquiry will continue.

The notion of model version was introduced in order to distinguish a particular system dynamics model and the mental model it represents from the model at a higher level, where it persists over time, independently of the changes that happen inside it. It was suggested that the differences between successive versions of a model represent what has been learned in the inquiry process. Resources, Sectors, Decisions and Loops have benn proposed as set of structural elements, and the Insertion, Modification and Deletion indicators capture theses differences. They have been used to detect Growth, Correction and Shrink in the general model, which in turn enabled us to see a Convergent or an Erratic evolution. Thus we were able to give the differences a meaning in terms of the learning process.

This seemed to be a valuable possibility, at least in conceptual terms; however, its practical usefulness remains to be tested. The author's query to the system dynamics mailing list has generated helpful answers and models, and a future paper will report on the progress made.

References

Argyris, Ch. y Schön, E., 1996. Organizational Learning II, John Wiley

Dewey, J., 1938. Experience and Education, Kappa Delta Pi

Dewey, J., 1991. How we think , Prometheus Books

Kolb, D., 1984. Experiential Learning: Experience as the Source of Learning and Development, Prentice Hall

Lewin, K., 1951. Field Theory in Social Sciences, Harper & Row

Morecroft and Sterman, 1994. Modeling for learning organizations, Portland, Oregon : Productivity

Perice, Ch, 1877. The fixation of belief, Popular Science Monthly 12 (November 1877), 1-15, available at http://www.peirce.org/writings.html (08/22/2003)

Schaffernicht, M., 1999 "Managing Improvement amongst Autonomous Actors with OMCA - the case of the Chilean Educational Reform", Proceedings of the 17th International Conference of the System Dynamics Society, Nueva Zélanda, 1999

Schaffernicht, M., 2001" A Method for Managing Organizational Learning", Proceedings of the 5th World Multiconference on Systemics, Cybernetics and Informatics, vol. II, p. 215-220, U.S.A., 2001

Schaffernicht, M., 2002. "Observer, Modéliser, Construire et Agir comme un Système Autonome: une Méthodologie pour l'Apprentissage dans les Organisations" [Observing, Modeling, Constructing and Acting as Autonomous System: a Methodology for Learning in Organizations], Doctoral Dissertation, 12/11/2002 University of Montpellier (France)

Senge, P., Ross, R., Smith, B., Roberts, Ch. and Kleiner, A., 1994. The fifth discipline fieldbook : strategies and tools for building a learning organization, London : Nicholas Brealey,

Sterman, J. 2000. Business Dynamics: Systems Thinking and Modeling for a Complex World, McGar Hill, 2000

Sterman, J. 2002. All models are wrong - reflections on becoming a systems scientist, System Dynamics Review Vol. 18, No. 4, (Winter 2002): 501–531

Wolstenholme, E. 1993. The evaluation of Management Information System : a dynamic and holistic approach, Wiley, 1993

Back to the Top