Implicit Minimum Requirements for First Draft Models also Provide a Starting Point for Better Reviews, and Quality, of Academic Models

Richard G. Dudley
rgdudley@gmail.com

Abstract

Minimum requirements for first draft models are an implied component of SD modeling best practice. Clear specification of these basic requirements can also help provide a better framework for reviewing "academic" SD models to be published in peer-reviewed journals or other outlets. This would also help limit the dissemination of poor quality SD models. Suggested minimum characteristics for first draft working models provided herein are a small subset of characteristics of a “good” model, not a substitute for those characteristics. Approaches for implementing, and extending, such requirements are discussed.

Keywords: system dynamics, model quality, academic models

Introduction

Recently, on the System Dynamics Society’s mailing list, there was an extended discussion concerning the following question: Do marginal models marginalize modeling? This question is linked to concerns that wide dissemination of poorly designed models can negatively affect the general perception of system dynamics modeling. It is likely that user friendly modeling software, although extremely useful for building good models, contributes significantly to the wider availability of bad models, increasing the need for better dissemination of good system dynamics models, and methods for their creation.

With that in mind I am interested in better defining the qualities of a minimum acceptable model in the most basic sense. Here I am thinking especially of models which are a part of published “academic” papers. As most readers are aware there is a significant literature on approaches for creating good system dynamics (SD) models (See introduction in Martinez and Richardson 2003). If followed, these approaches will increase the likelihood that high quality models will result. The related subject of model validation has also received considerable attention (e.g. Barlas 1996; Barlas and Carpenter 1990; Coyle and Exelby 2000).

In their investigation of SD best practices, Martinez and Richardson (2003) used the following categories: problem identification and definition; system conceptualization; model formulation; model testing and evaluation; model use, implementation and dissemination; and design of learning strategy/infrastructure. Here I focus on the early phases of model formulation as the source of required minimum model qualities.

Implicit use of a minimum acceptable model

When we think about suggested procedures for creating good system dynamics models we face an apparent dilemma: Good modeling practice implies an understanding of the problem. But, by our definition, clear understanding of the problem requires a good model. In fact good modeling practice is dependent upon model-based discussion among domain experts and stakeholders and modelers. Procedures for good model building sensibly require a certain familiarity with both the domain and the modeling process. Understanding of the domain and problem at hand is strengthened by having a good model. In other words, seemingly one needs to understand the model before it has been created.

Of course, in reality, this is not the case. A good model is created in an iterative manner. We start with a very basic model and work from there improving and discussing as we go. However, at some point in this process we have *a minimal working model* which serves as a realistic starting point for discussion. What are the qualities of such a model? This question is important, because it can also define the *minimum* requirements for academic models.

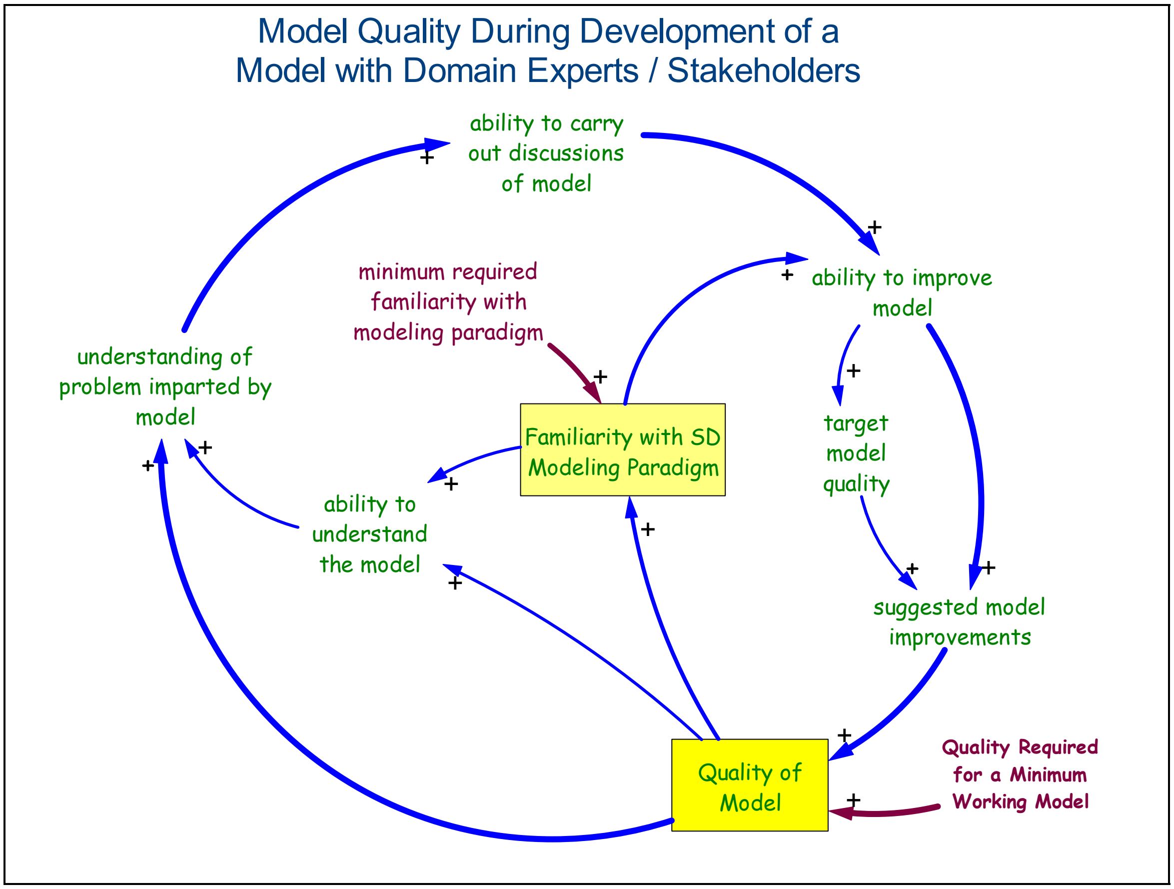

Figure 1. Development of model quality during sessions with domain experts and stakeholders requires two starting points, which we can think of as initial values: A minimum familiarity with SD modeling, and a model that has some minimum characteristics that will allow further discussions and improvement.

One valuable function of models, particularly system dynamics models, is the function of the model in clarifying rationale for proceeding with a certain course of action. In theory a system dynamics model should clarify thinking about a particular problem so that the issues associated with that problem are more understandable. Implicit in this part of the system dynamics paradigm is the idea that, at least initially, there is *likely to be disagreement* on the underlying structure and rationale provided in the model. That is, the model, during its creation, is *a tool for discussion which may reveal disagreements* and differences in how the real world should be represented. The review of underlying rationale and subsequent alteration of model structure are key steps in good model development. Also, a good model-based discussion may reveal a variety of possible policies that might be pursued, not just one.

As a consequence it is obvious that, initially, it may be *impossible* to build a model on which all stakeholders and the domain experts agree. That is, best modeling practice includes, by definition, the use of an unfinished basic model in the discussions leading to a 'best' model.

Academic models: A special case of the same question?

Models which are the focus of papers submitted for publication can be viewed as a special case with regard to minimum model quality. Such papers are usually destined for academic journals, but publication may also mean the reporting of model-backed policy assertions for review by larger, often public, audiences. For example a public agency may use a model as part of a report backing assertions about a flood control project, agricultural subsidies, greenway development, or tax policy. Such academic models differ from commercial system dynamics models (Coyle and Exelby 2000) that likely have intense review and negotiation with a client throughout the modeling process. Public policy models may be intermediate between academic and commercial models in that a contract to have a model developed may exist. Such a contract may or may not have the same level of review that might occur in a commercial model, and in any case faces further scrutiny when presented for public review. Academic models, on the other hand, typically rely on anonymous reviewers who check the quality of a submitted paper.

Defining the minimum qualities for the first step SD models can help us define bare minimum standards for such academic models. There is often a lingering disagreement over what is a best model for a particular purpose, so the creator of an academic model can claim that criticisms of a model under review merely reflect differences of opinion. On the other hand if models must meet some minimum standard then increased transparency and understanding of model logic is more likely. Disagreements, that occur can then be based on assumptions stated in the model. Obviously, all models should be beautifully crafted, fully understandable, with a compelling message. While only a few models will meet those criteria, adherence to minimum standards is a one reasonable action that might improve overall quality of published academic models.

Adherence to minimum standards may help limit dissemination of poor SD models via academic journals. If minimum standards enhance reviewers' ability to understand models, perhaps fewer papers based on poorly constructed models will be accepted. Readers who see the resulting models will be reading better papers, at least from an SD perspective. The final version of a published model may still be a discussion version in the eyes of other beholders, but models meeting minimum standards will have a better chance of becoming better defined and verified models.

A second concern regarding the review of academic models is the fact that not all reviewers are familiar with the SD paradigm. Reviewing an SD model without the necessary minimum understanding weakens the review process and can result in poor decisions regarding the review. This might lead to the acceptance of poor, or the rejection of good, models. Minimum model requirements can help alleviate that problem.

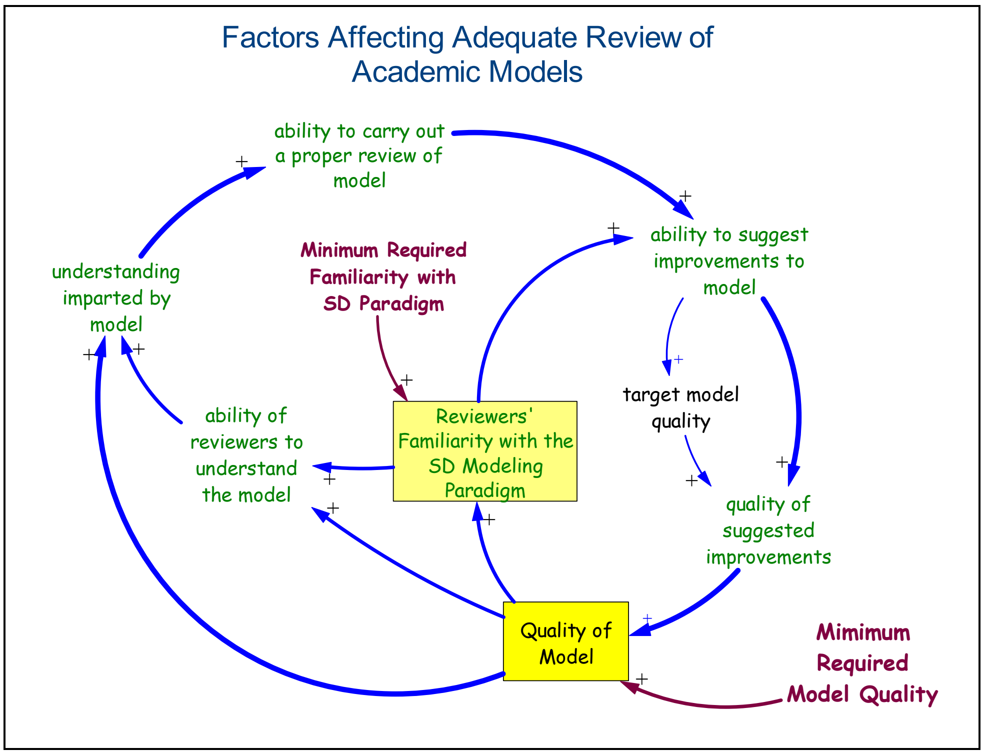

Figure 2. A number of factors affect a reviewers ability to properly review papers based on models using the SD paradigm. Assuming the domain knowledge of the reviewer is high, the issues most important for review are: familiarity with SD modeling, and the basic quality of the model.

Minimum model standards

One of the difficulties faced in reviewing a model is the ability of a reviewer to understand it sufficiently to allow review. Consequently, key characteristics of a minimum qualifying model are those characteristics which make the model understandable, both in terms of the model's purpose and in terms of its structure and operation. In fact, if we allow that a minimum model may still not be an agreed-upon model then "fully understandable to the intended audience" may be the primary criterion at this point. Other additional criteria determine if it is, overall, a good model.

Here are suggested qualities of a first draft model.

Qualities of a First Draft Model

1. Model has a clearly stated purpose which may include:
    a. reference modes for key model components.
2. Model has clearly stated domain boundaries
    a. which are realistic for the problem under study.
    b. which include only those components necessary for understanding the problem under study.
3. Each model component
    a. is clearly defined with a brief description.
    b. has units of measurement, and these are consistent with those of other components.
    c. has a clearly formulated equation.
4. Model structure
    a. is clearly laid out.
    b. clearly identifies stocks, flows, and auxiliaries.
5. Behavior of model outputs must be reasonably realistic compared to what is known about the problem being modeled.
6. The model will run without obvious errors
    a. and can pass simple extreme conditions testing (e.g. running the model for and longer period, changing some key variables to zero, etc.).
7. The model, and model equations, are available for examination, and can be run, and examined, without cost or undue difficulty.

Importantly, there may still be disagreement on included components, their units and equations, and model structure, until a later point in model development. In fact, this should be part of the review process.

My point here is not that these characteristics will necessarily make a good model, but to facilitate proper review a good model must have these minimum characteristics. If it doesn't have these characteristics it should be returned to the authors of the article without additional review. Ideally these should be minimum model requirements for initial submission of an article or report.

A peripheral question concerns the target audience. I'm assuming here that the audience of an initial model consists of people who have an interest in the problem and have knowledge, or an ability to acquire knowledge, about the domain and problem under consideration. They must also have a reasonable familiarity with system dynamics modeling.

Given the above information I see four phases of model development which parallel good modeling practice as expressed by others.

Phase 1 model: Satisfies Basic Requirements. A minimum working model that is fully understandable to others as defined above.

Phase 2 model: Model Under Development. Model is currently under development using iterative review and improvement. At all times it satisfies basic requirements.

Phase 3 model: A completed model. Ready for "implementation" although it may still be revised and improved.

1. Each model component has been critically assessed and reviewed.
2. Extreme conditions testing has been carried out.
3. Extended structural validity tests have been carried out.
4. Feedback with domain experts/stakeholders (as appropriate) has been used in model development.

Phase 4 model: A model that has proved useful in the real world. Suggested policies were successfully implemented.

Potential for further improvement of "academic" SD models

Minimum model requirements might also provide an opportunity for *overall quality* improvement of SD models published in, especially, non-SD journals and similar outlets. Unlike commercial SD modeling, academic research using SD modeling relies to a large extent on peer reviewed journals to enforce model validity and usefulness. Until recently reviewers of many, if not most, computer model-based papers had limited, or no, access to the models used. This situation is changing. With electronic communication the models on which such papers are based can be made available to reviewers and readers. The provision of simple guidelines for reviewing model-based papers can assist reviewers, and the bare minimum test is suggested as a starting point. Models not meeting the minimum standard would not be reviewed further. Additional guidelines could be provided for review of models passing the initial test.

Minimum model standards are easier to define and implement than are true model validity and verification requirements. Minimum model standards primarily address the readability and accessibility of the model, not its ultimate usefulness or level of correspondence with the real world. Minimum model standards do not supplant either model usefulness or model validity as essential parts of the good modeling protocol.

Although it is easy to define minimum standards, for whom are they intended? Authors of papers for a system dynamics conference? Authors of academic journals and reports? While I can see these standards as being the minimum threshold for acceptance of papers at the SD conference, I am more concerned about models using the SD paradigm which are published in non-system dynamics journals. Such models are more likely to have been created, and are more likely to be reviewed, by those without SD training.

A related question involves the definition of a system dynamics model. Members of the System Dynamics Society probably have a fairly clear idea of what this definition might be, but authors with peripheral knowledge of SD may use a completely different definition, or none at all. Many of the people who use system dynamics software do not use it to create what *we* would call system dynamics models. Some of these models appear to be perfectly reasonable scientific models based on systems of differential equations.[1] Others are attempting to create models that we would call system dynamics models, but they are not good models, by our definition. It appears that a fair number of such models use system dynamics software without an understanding of the system dynamics modeling paradigm. Such models may exhibit, for example: no units, apparent lack of understanding about the concept of flows, extensive use of nested if then else statements, and other warning signs of modeling techniques inadvisable in a system dynamics model. Model structure is typically a very confusing, highly detailed, spaghetti diagram.

Often the authors of such models are knowledgeable about their domain and may have significant computer modeling experience.[2] They have, apparently, decided to use user friendly system dynamics software which allows them to quickly put together a working model. They may not realize that the use of SD software implies a particular modeling paradigm, and that use of it to develop other sorts of models may give unexpected results. I expect that some readers have heard new SD modelers say: "I made the model… but the software doesn't work right."

It is my belief that education about system dynamics modeling via a few well-placed articles in non-system dynamics journals would be extremely valuable. Not only would these articles provide a clarification to those using such software, but they could also improve the overall use of system dynamics software as a modeling tool. Such a paper might be disguised as a review of system dynamics tools, maybe in comparison with other tools if an appropriate array of authors could be found. Such an article might also be used to promote minimum model requirements for submitted model-based papers. Such papers might be couched in terms of presenting minimum model requirements.

Additional standards / guidelines for reviewers?

If one is in favor of having some sort of minimum standard, and believes that these can be useful in some way, then perhaps we should also be in favor of higher standards. Since there is a reasonable amount of information regarding modeling best practice perhaps that should be required. But how could such standards be enforced?

A better approach might be to encourage guidelines for reviewers of model-based papers. This may not be easy. With regard to the use of statistical analysis in published papers it would seem that correct statistical procedures would be fairly well-established. However, Ioannidis (2005) claims that most published scientific findings are incorrect largely because of flawed statistical interpretation. In fact, we might get the feeling that it doesn't really matter if scientific papers, and "academic models", are wrong, because nobody reads them anyway! At least Meho (2007) reports that only half of scientific papers are actually read. So if models are poorly designed but nobody reads the papers that use them, does it matter? Perhaps that is an overly cynical view.

I think the publication and dissemination of bad models *does* make a difference. People who do modeling within a specific field actively seek examples within their own field. People who do ecological or natural resource modeling, for example, will read a subset of papers about ecological modeling. If the models they read are poor models built with user-friendly software in the system dynamics style, the system dynamics paradigm itself is in danger of being thought marginal. The statement “I tried using that system dynamics software, but it doesn’t work right” becomes a the refrain of the uninformed. Attempts to implement minimum modeling standards, and to more broadly disseminate understanding of the SD paradigm can help to minimize that possibility.

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Notes

[1] The system dynamics modeling paradigm is well developed and tends to focus on models involving soft, as well as hard, variables and on solving identified problems in complex systems. It is my understanding that the software itself has no such restrictions. The software only assumes that the model is set up as a system of interlinked differential equations. As a consequence it is perfectly reasonable to use a system dynamics software package to build a structure of interlinked differential equations without any regard for the other trappings of system dynamics modeling. Variables can be defined as x, y, and z. Perhaps there is less need for clarity if the intended audience is reasonably familiar with the domain and approach being used. There are a number of published academic models using system dynamics software in this way. Most of these models may be good in the sense that they're accurate representations of the real world.

[2] Also, the differences in philosophy between computer modeling and computer programming cannot be ignored. While the two overlap, the modeling paradigm is more about envisioning how components of a system fit together, while programming is more about using input data to determine possible outcomes. Modeling is more about fitting components into a whole, while programming is more about creating a complex recipe for calculation.