System Dynamics Model Correctness Checklist

SYSTEM DYNAMICS IN EDUCATION PROJECT
SLOAN SCHOOL OF MANAGEMENT
MASSACHUSETTS INSTITUTE OF TECHNOLOGY
By: Danny Lai and Rebekah Wahba

"Perfect models" are rare in Systems Dynamics because the "correctness" of model is relative to its purpose and varies widely, depending on the modeler, users, and modeling conventions. Below are some pointers one should use when building and simulating models. They include some accepted modeling standards, and also tips to check if your model "works".

1. **Units check** – Vensim and some other programs (Stella, iThink etc.) have built-in units feature that will check all equations for consistency in units. (That is to make sure the left and right side of all equations have the same units.) This feature is a valuable tool that can be used to check that valid dimensions, constants and equations are used. One must check models for dimensional consistency before simulating either using the software feature or manually.

2. **Naming variables** – A general element naming convention has been proposed by Ventana, the makers of Vensim. The first letter of Stock names should be capitalized; CONSTANTS should be in all capitals, and names of all other variables, including flows are all lower case. Use names that clearly explain what a model element represents. In general, the word "rate" is reserved for flows. For example, do not confuse birth fraction, with birth rate.

3. **No constants embedded in equations** – It is often tempting to simplify equations by using numeric constants embedded in equations. One must not do so! A good model will show all constants explicitly as individual elements. One must be able to recognize all model elements at a glance. Name the constant and use the constant name in the equation. This allows constants to be recognized and changed easily in future simulations, without changing any equations in the model.

4. **Do not mention parameter values in the documentation** – The documentation complements the equations and should merely describe what the equations mean, and contain special notes. Frequently, constants are changed and sensitivity analysis is performed on models, and parameter values are changed in the equations (in the case of constants). If parameter values are mentioned in the documentation, they will have to be changed every time the equation is changed. This can be tedious and confusing as a reader will see two different numbers if the documentation is not updated, (See #3). Not mentioning parameter values in the documentation keeps it robust and avoids potential confusion.

5. **Choose appropriately small time steps** – Choose the time step to be about one-eighth the value of the smallest time constant in the model (the time constant is the reciprocal of a growth or decay fraction). Doing so will increase the frequency at which the software solves the model equations, improving the approximations of continuous time and avoiding some mathematical errors.

6. **Stock values can be changed only by flows** – The only model elements with direct connections to stocks are flows. No constants or auxiliary variables should directly enter the stock equation, except for the initial values of the stock, (See #11).

7. **Every flow should be connected to a stock** – A flow only increases or decreases a stock; it cannot be used as a source of information in a model as it cannot be measured, (See #8). A flow unattached to a stock serves no purpose in the model, as it does not affect anything.

8. **Flows should not be linked to auxiliary variables or to other flows –** Flows are instantaneous and cannot be measured in real-time. In fact, flows can only be measured by calculating the change in stock value per time unit. Furthermore, it takes time for information to move from one flow to another. So a flow theoretically cannot give another flow a value equal to itself in the same time period. Besides, as flows cannot be measured, clearly one flow cannot pass information to another flow. Therefore, one must not use a flow to provide information to an auxiliary variable. If two flows are defined by the same structure, then one should use the same structure and equation to define both flows (and be a little redundant) instead of simply connecting the two flows.

9. **Stocks should not be linked to stocks** – A stock is the integral of a flow, (See #6). To show information transfer between two stocks, connect the first stock to the flow of the second stock. Be sure to check the units.

10. **Using IF THEN ELSE, MIN/MAX and other logic statements** – Almost no real-life situations behave according to IF THEN ELSE or MIN/MAX statements. Change is almost always gradual and not sudden like such functions suggest. One must use table functions to avoid discontinuities introduced by such statements.

11. **Use of Initial Values –** When initial values are used in a model, they should be clearly specified and connected to the model. The newest versions of most of the popular modelling software enforce this practice. There are occasions though, where the software does not allow for these connections, another way to explicitly connect the initial values (e.g. Word) should be used. This modelling convention makes it considerably easier to change initial conditions while running simulations.

12. **Curving connectors** – This issue deals with aesthetics. The connectors that link one variable to another should be curved as a model with curved connectors looks nicer, and the feedback loops are easier to trace.