Guided Study Program in System Dynamics
System Dynamics in Education Project
System Dynamics Group
MIT Sloan School of Management[1]

Assignment #14

Reading Assignment:

- *World Dynamics*,[3] by Jay W. Forrester, Chapters 5, 6, and 7.

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[3] Forrester, Jay W., 1971. *World Dynamics*, (1973, second ed.). Waltham, MA: Pegasus Communications. 144 pp.

Exercises:

Please complete the reading assignment before you tackle the exercises.

In *World Dynamics*, Prof. Forrester tests different scenarios with the world model in order to understand how different policies will or will not bring a smooth transition to global equilibrium. In this assignment, you will use Vensim PLE to test out the same scenarios and try to explain why the model generates the behavior observed. Ventana Systems has included with Vensim PLE a copy of the *World Dynamics* model, and many other models. The model should be located on your hard drive at:

Vensim\Models\Sample\Other\World.mdl

(Ventana Systems also provided a folder named Wrld3-91. World3 is not the *World Dynamics* model but the revised *Limits to Growth* model that was examined in *Beyond the Limits*.)

The world model contains what Vensim calls "multiple views," a feature enabled on the more advanced versions of the software. With the multiple views, the model is divided into three screens, with ghost variables linking variables between screens. The three sectors of the world model are: Population and Food, Capital and Quality of Life, and Pollution and Resources. To switch between sectors, click on the task bar option labeled "Population & Food" in the lower left hand corner of your screen and choose from the menu. The taskbar will then read the title of the current sector.

First, simulate the model as it is, in the base run case that Prof. Forrester first presents in *World Dynamics*. Then, work through the following exercises one at a time, changing the appropriate parameters and graphing the test simulation along with the base case, in order to have points of reference from which you can contrast the differences in behavior. After you compare the two runs, provide in your solutions document a verbal explanation of why the policy changes produce the behavior you observed. Feel free to refer to Chapter 3 of *World Dynamics* for detailed explanation of each variable in the model. You will notice that we have already modeled several components of the world model. Only refer back to Chapters 4 and 5, which contain Prof. Forrester's explanations of the behavior generated by the different scenarios, after you have worked through the model on your own.

As you can see, the most difficult part of this assignment will be to go through the model and pick out which limits to growth or which interplay of feedback loops are driving the system under the different scenarios. To get you started, we thought that we should provide you with an example of how a typical SDEP student might tackle such a question. She would graph the base run, then create a new dataset in which she changes one parameter in the model. She graphs both datasets on the same graph and observes that, in the test simulation, the stock of population decreases much faster and to a lower level than in the base run. She wants to understand what caused the population to drop. She graphs some of the other important stocks in the system, like the levels of capital, pollution, and natural resources to see how their behavior changes. Do the changes come before or after the time at which the population collapses? She makes some guesses as to what might have happened, and then starts at the root of the problem, population, tracing backwards. She checks the graphs of the birth and death fractions to find out that the birth fraction remained quite stable, but the death fraction sharply increased. She then

checks the graphs of the different multipliers that make up the death fraction to see which one or which ones show different behavior from the base case. Then, concentrating on those particular multipliers that show surprising behavior, she uses their constituent equations (or the causal-tracing feature provided by Vensim) to determine which variables caused that behavior, digging a layer deeper. When she comes around full circle to one of the variables that she had previously identified, she will have found one of the key feedback loops driving the behavior of the test simulation.

One more hint: the modelers at Ventana Systems used a special structure to make it easier to make policy changes to the world model. The structure is as follows:

$$\text{IF THEN ELSE (Time} > \text{switch time \# ,}$$
$$\text{parameter normal 1 ,}$$
$$\text{parameter normal)}^4$$

The switch time is set to be 1970, the "present day" used in the model (the year that *World Dynamics* was written). "Today" we have the option of making policy changes that will be effective into the future. In the base case, the "parameter normal 1" is the same as the "parameter normal." When you simulate the model, the "parameter normal" will be effective until the switch time, 1970, after which time the "parameter normal 1" will kick in. To make a policy change, you just need to set "parameter normal 1" to a new value. Then, when you simulate the model, the new policy will come into effect in 1970.

Now, to work! For each scenario, describe the behavior you observe and explain how that behavior is generated by the model. Provide any graphs needed to support your explanation, but the explanation is the most important part of your answer.

Scenario #1

Reduce the "natural resource utilization normal 1" to 25% of its original value.

Scenario #2

Set the "natural resource utilization normal 1" to 0 and reduce the "pollution per capita normal 1" to 10% of its original value.

Scenario #3

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[4] Please note that there is a typo in the equation for the "pollution generation" rate. The equation should be:
pollution generation rate = Population * IF THEN ELSE (Time > switch time 6 ,
                                                              pollution per capita normal 1 ,
                                                              pollution per capita normal)

and not:
pollution generation rate = Population * IF THEN ELSE (Time > switch time 6 ,
                                                              pollution per capita normal ,
                                                              pollution per capita normal 1)

Set the "natural resource utilization normal 1" to 0 and reduce the "pollution per capita normal 1" to 10% of its original value. Change the table functions "deaths crowding mult tab" and "births crowding mult tab" so that they level off at 1.0 for any crowding ratios larger than 1.0.

Scenario #4

Increase the "capital investment rate normal 1" by 20%.

Scenario #5

Reduce the "birth rate normal 1" to 70% of its original value.

Scenario #6

Increase the "food coefficient 1" by 25%. Explain what the food coefficient represents.

Scenario #7

Reduce the "natural resource utilization normal 1" by 75%, reduce the "pollution per capita normal 1" by 50%, reduce the "capital investment rate normal 1" by 40%, reduce the "food coefficient 1" by 20% and reduce the "birth rate normal 1" by 30%.

Final Exercise

Find your own combination of policies to apply to the world model that improves the smooth transition towards a sustainable equilibrium. Explain how the behavior observed results from the policies changes you made.