System dynamics learning lab – part II

System dynamics in practice

We will now put the concepts of stocks, flows and feedbacks into practice. The models below are built and run in the web-based system dynamics platform InsightMaker.com. Let's work through tasks 1-2 together to get familiar with the workings of InsightMaker. After gaining some experience, you can then choose from tasks 3-5 to work through.

Task 1 – Introduction to InsightMaker

1. Using your favourite web-browser, go to InsightMaker.com and click 'Log In' in the top righthand corner of the page. Enter the following credentials to access the models:
   Username: ANHSystemDynamics@gmail.com
   Password: A4NHSystem
2. You will see the ANH_Population model on the dashboard. ***Please left click on the model, then go to the top right-hand corner and press 'clone insight'***. When prompted on the next page, press 'Clone'. When the model reappears, go to the righthand side and press 'Edit Info'. Rename the model's title to YourName_Population (e.g. GregCooper_Population) and then press 'Save'.

3. You will now see the InsightMaker canvas with the stock and flow structure of the semi-defined population model. For now, let's concentrate on familiarising ourselves with the different InsightMaker controls.
4. The toolbar (above) is the control panel to build, edit and run the models.
   a. 'Settings' allows you to change the simulation length and duration, as well as the model's integration method (but don't worry about that here!). Click 'Settings' to adjust the simulation length from 15 to 30 years.
   b. Click on 'Add Primitive' to view the range of model building blocks. Notice how we used *stocks* and *variables* during the conceptual phase of this lab.
5. Moving away from the toolbar, hover over the flow named 'Births' and click on the small equals sign that appears. The box that appears allows the equation of the flow to be modified and its units to be added (e.g. births/year).

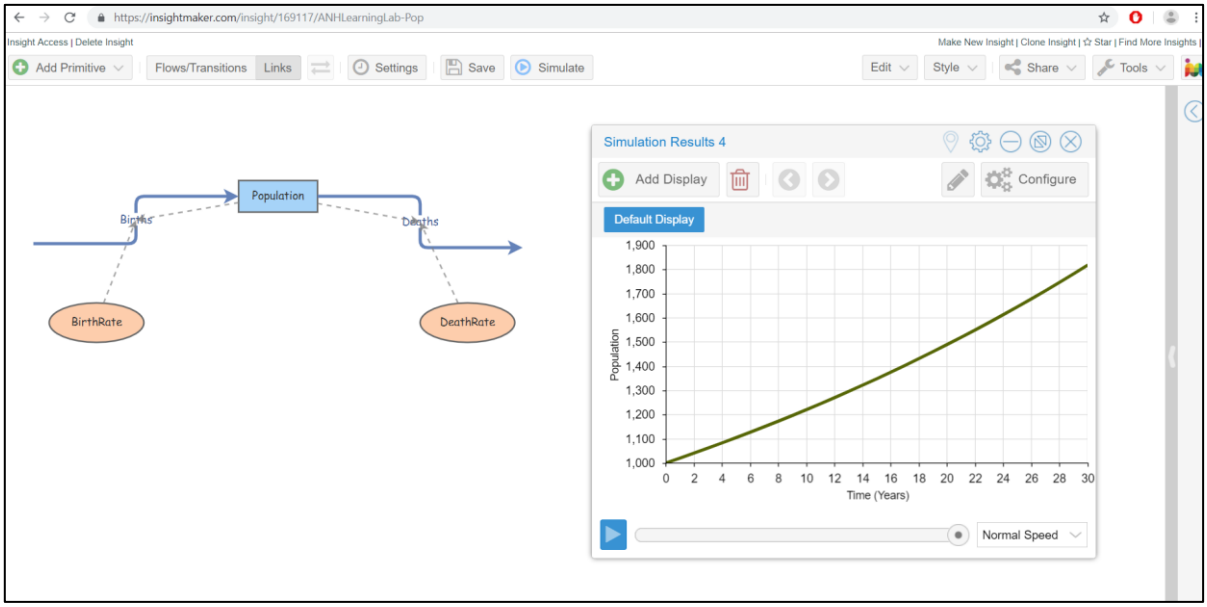
Task 2 – Completing the simple population model

1. Think back to our conceptual modelling. You will notice that the *DeathRate* is missing from the InsightMaker model (i.e. the number of deaths per 1000 population per unit time). Complete the model through these following steps:
   a. Define the *DeathRate* as a variable, as we assume it remains constant over the simulation. Click on 'Add Primitive', then 'Variable'. You will see an orange oval titled *New Variable* appear on the model canvas.
   b. Click and drag the *New Variable* into position (i.e. somewhere near the *Deaths* flow).
   c. Double click on the oval to rename it to *DeathRate* (italics not required).

d. To add its value, hover over the *DeathRate* oval and click on the equals sign that appears. In the box that appears, enter *6.2/1000,* meaning a death rate of 6.2 people per 1000 population per timestep.
e. Now we need to connect the *DeathRate* to the *Deaths* flow. First click 'Links' in the toolbar, before hovering over the *DeathRate* variable. Click on the little blue arrow that appears in the oval, before dragging the link up to the *Deaths* flow. Once complete, you will see a dashed grey line connecting the *DeathRate* to the *Deaths* flow.
f. Finally, we need to enter the equation for the number of *Deaths* per timestep. Hover over *Deaths,* click on the equals sign and enter *[Population]*[DeathRate]* in the equation box that appears. This can be achieved by clicking on the variable's names displayed in the righthand column of the equation box.

Task 3 – Simulating the model and graphing its outputs

1. The population model is now ready to simulate! Follow the instructions below to run the model, graph the outputs and change the outputs displayed in the graph.
   a. To simulate the model, click 'Simulate' on the toolbar. You should see a time-series graph appear.
   b. To visualise only the population trend, click 'Configure' within the graph display, before checking that *Population* is the only variable listed under the 'Data' box. If you need to remove variables from the graph, click on the little grey crosses next to the variable names. The canvas should appear as below.

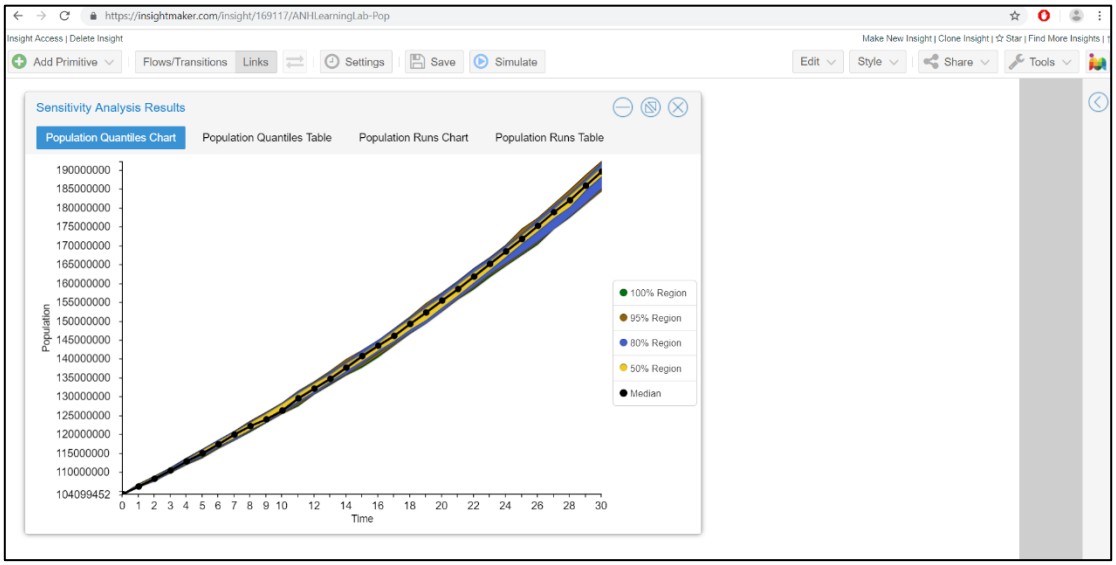


   c. To add a new display, click 'Add Display'. Add *Births* and *Deaths* to the display to view them separately from the *Population* trend.

Task 4 – Model sensitivity analysis

Sensitivity analysis helps us to understand the degree to which model outputs (e.g. the population trend) are sensitive to any particular driving variable. This information is important when assessing model uncertainties, as ideally, we would like the model's behaviour to remain consistent across the error bounds of our data used to inform the model. Finding that the model is highly sensitive can undermine the confidence associated with the simulated trends. Follow the steps below to conduct simple sensitivity analysis:

1. We will assess the sensitivity of the population trend to the uncertainties in the *BirthRate* estimate.
2. To do this, InsightMaker requires random inputs to see how the outputs vary.
3. Hover over the *BirthRate* variable and click the equals sign to alter the value. Click on the 'Normal Distribution' function under the 'Random Number Function', and enter *26.3* for the mean, and *2.45* for the standard deviation (calculated from district-wide birth rates across Bihar, 2011 Census of India), all divided by 1000.
4. Click on 'Tools', 'Sensitivity Testing…' and fill out the box that appears. Enter *Population* into the 'Monitored Primitives' box to visualise how the uncertainties in the *BirthRate* estimation influence the *Population* trend.
5. Press 'Run Analysis' and visualise the outputs.



6. Repeat this analysis for the *DeathRate* variable. Change the *BirthRate* back to *26.3/1000*, before entering *RandNormal(6.2, 1.1)/1000* for the *DeathRate*. How does the sensitivity (i.e. the spread of outputs) of the *Population* trend to the *BirthRate* compare to the sensitivity to the *DeathRate?*

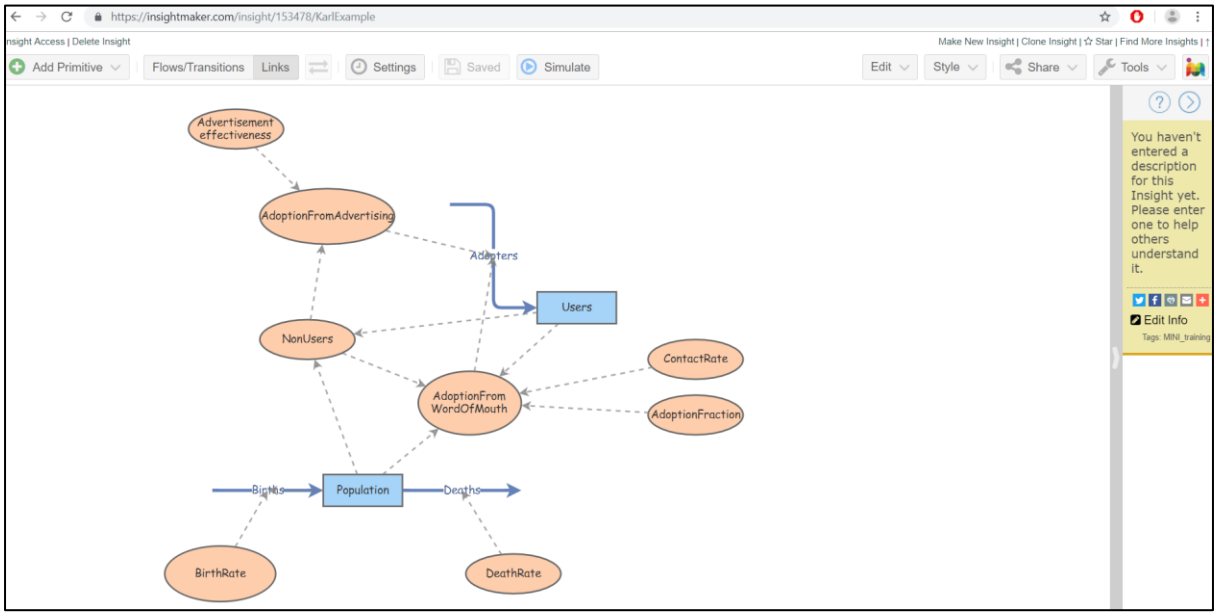
Task 5 – Simple model of agricultural technology adoption

***** Before editing the ANH_Adoption model, please clone it and save it under your name (as per the population model in task 1)***.**

The population model from above has been extended into a simple model of agricultural technology adoption across a population (based on *Bass 1969 Management Science* and *Rodgers 1983 Diffusion of Innovations*). Essentially, the number of technology users increases by *AdoptersFromAdvertising* and *AdoptersFromWordOfMouth,* with the latter simulating the communication and mixing effect between technology users and non-users. See below for the default parameter values:

Variable name	Value	Description
Users	0	People using the technology
Adopters	AdoptionAdvertising + AdoptionWordMouth	Total number of new adopters per unit time
AdoptionFromAdvertising	NonUsers * AdvertisingEffectiveness	Absolute number of new adopters taken in by advertising
AdvertisingEffectiveness	0.01	The proportion of non-users convinced to adopt by advertising

ContactRate	100	Arbitrary number of interactions between users and non-users per time-step
AdoptionFraction	0.0005	Proportion of non-users encouraged to adopt after contacting users
AdoptionWordMouth	(ContactRate* AdoptionFraction*Users* NonUsers)/Population	Absolute number of non-users encouraged to adopt after contact with users, per time-step
NonUsers	Population - Users	People not using the technology
Births	Population * BirthRate	Births per timestep
Deaths	Population * DeathRate	Deaths per timestep
BirthRate	26/1000	Births per 1000 population per timestep
DeathRate	6/1000	Deaths per 1000 population per timestep
Population	1000	Arbitrary total population of model



Feel free to work through the following activities to extend the simple model and explore its system dynamics! ******However, before editing the ANH_Adoption model, please clone it and save it under your name (as per the population model in task 1)***.**

1. **Identifying feedback loops:** InsightMaker keeps track of the model's feedback loops, which can be useful to check the InsightMaker model against any conceptual work (e.g. causal-loop diagram). Click 'Tools' → 'Identify Loops…' to view the list of feedbacks. Note that the tool does not say whether the feedbacks are positive or negative.

2. **Sensitivity analysis:** How sensitive are the model outputs (i.e. the number of agri-tech users) to changes in the parameter values?
    a. Choose a variable to introduce randomness (e.g. *ContactRate, AdoptionFraction* or *AdvertisementEffectiveness*).
    b. Use one of the 'Random Number Functions' to define the error bounds of the variable selected [e.g. *AdvertisementEffectiveness = Rand(0.005, 0.015)*].

c. As per task 4, use 'Tools' → 'Sensitivity Testing…' to set up the sensitivity analysis. Choose the outputs to be plotted before pressing 'Run Analysis'.
d. Compare the sensitivity of different model outputs (e.g. *Users*, *Population…)* to the possible values of different variables (e.g. *ContactRate, AdoptionFraction…*).
e. Remember to test only one driving variable at a time and reset each parameter to its default value before introducing randomness to the next variable.

3. **Introducing delays:** Suppose the technology has a ten-year limit, meaning the users who adopt in year 10 must give up the technology in year 20.
   a. Add a new variable called *Disadoption*
   b. Click on *Disadoption* equals sign and parameterise the equation with a 10-year delay: *Delay([Adopters], 10).*
   c. Now we need to connect this variable to an outflow from the *Users* stock. Draw the outflow from *Users*, then connect *Disadoption.* Make the equation of the new outflow equal to *Disadoption.* This will mean any adopter will have to dis-adopt after being a user for ten years.