Exercise 1: Sensitivity Analysis

Sensitivity analysis forms a component of model testing and is undertaken once a model is exhibiting satisfactory reference behaviour. In other words there is a reference run (simulated reference trajectory) with which to compare model outcomes (alternative trajectories) when model parameters are perturbed. Before commencing a sensitivity analysis you need to be able to describe and explain the reference run behavior.

1. Rate sensitivity analysis

Conduct a full rate sensitivity analysis in which you vary the rates in the Community Aquifer model by + or – 1%. Describe the procedure you follow. Note that you will need to determine the metrics by which you will evaluate your rate sensitivity analysis and justify your choice. Describe your results briefly.

The purpose of rate sensitivity analysis is recognizing to what extent the change of assumed values of parameters could affect the numerical values of the results. Therefore, some steps needs to conduct in this type of sensitivity analysis:

(1) Specify which parameters to vary
   a. Make a list of all parameters in the model
   b. Assess the uncertainty of value of each parameter; mark them as "low", "medium", 'high" and "very high".
   c. Assess the extent of influence of each parameter in its sub-system; mark them as "low", "medium", 'high" and "very high".
   d. Select the parameters whose both uncertainty and influence are high.
   e. Predict some impacts of each change in parameter and give reasons for it.

(2) Choose some state variables as performance indicators
   a. Review the list of problem owner and stakeholders involved.
   b. List some most important state variables to each stakeholder
   c. Choose a group of not more than 5 state variables from the above list as a final performance indicators

(3) Choose a metric to measure the effect: $\max \dfrac{|x_i - x_{iref}|}{|x_{iref}|} \quad \forall i = 1, n$

(4) Choose a time frame: Because the model is run for 50 years. So the chosen time frame is 10 years, which means for each parameter and variable, we have 6 values at 6 moments to compare with the base run.

Results:

There are around 27 parameters in the Aquifer model – such a big number that we could (should) not put all of them into the test in step 1. According to the size of model (which is really modest), the final list might include from 5 – 10 parameters. Moreover, the process of parameter assessment is highly based on intuition or personal experience of modellers. This very subjective process could depend on how sceptical the modellers are, the availability and richness of data, the time they could invest for inspecting data.

According to the **Appendix**

, we have the list of high important and uncertainty parameters:

(1) Delay time before leaving country
(2) Annual food requirement per person per year
(3) Cross sectional area aquifer
(4) Irrigation water need per meter square
(5) Percentage of salt in the topsoil seeps down into the aquifer
(6) Reference point of salt rate
(7) Salt effect multiplier

In step 2, there are 2 levels of stakeholders in this problem: high-level stakeholders such as government, UN, etc.; low-level stakeholders such as regional professional associations or organizations; ordinary inhabitants, etc.

- The high-level stakeholders could possibly take care of the overall picture, which includes Population, Volume of Aquifer, Total crops production, Total irrigated and non-irrigated land.
- The low-level stakeholders could possibly concern the available water per person, crops produced per person.
- However, in the position of modeller who needs to answer research question of relationship between climate change and refugees, I need the number of Emigrants and Salt concentration in the list.

So, to combine 3 point of views, the final list of performance indicators will be

- Population,
- Emigrants,
- Salt concentration,
- Crops produced per person per year,
- and Volume of Aquifer

To calculate the rate sensitivity analysis, we did the following steps:

(1) Run the Aquifer model in the base-run, which means all parameters are kept in initial default values.
    a. Annual food requirement per person per year = 80 kg/person/year
    b. Cross sectional area aquifer = 3,65 x 10^8 m2
    c. Irrigation water need per meter square = 700 litres/m2
    d. Percentage of salt seeps down into the aquifer = 100%
    e. Reference point of salt rate = 8000 mg/m2/year

    The salt effect multiplier was removed from the parameter list because it is a look-up function.

    The values of Population, Crops produced per person per year, Salt concentration and Volume of Aquifer are recorded at 6 moments: time = 0, 10, 20, 30, 40 and 50. These values would be considered as reference points. The Emigrants was removed from the variable list because it always fixes at value of 0 during the process.

(2) Increase and decrease 1% the value of abovementioned parameters. Only one parameter is varied each round while the remaining parameters are always kept at default values. The values of 4 variables are recorded in the same way, but separately for every parameter. The ±1% range of each parameter corresponds to the min and max of that parameter.

(3) Calculate the changing percentage of each variable compared to its reference point at each moment. The formula used is: $\frac{|x_i - x_{ref}|}{|x_{ref}|}$

For example: the following table 1 is the values of variable "Crops produced per person per year", respecting to default value and "-1%" changes of parameter "Annual food requirement per person per year" (which mean 80 and 79,2 kg/person/year) and different moments.

	VARIABLE: Crops produced per person per year						
PARAMETER: Min of Annual food requirement per person per year	Time	0	10	20	30	40	50
	Reference value (kg/person/year)	69,162	96,006	97,387	96,401	96,956	97,103
	New value (kg/person/year)	69,162	95,838	95,211	96,218	95,033	95,298
	Percentage of change (%)	0,000	0,175	2,235	0,190	1,984	1,859

Table 1

The following table is the summary of calculation for 5 parameters, 4 variables at 6 moments. The values of variables showed in this table are in percentage (%) unit.

Because the rate of parameter change is small (±1%), so the percentage change of variables is calculated till 3 digits after decimal point. In overall, most of percentage change of variables is 0. Some have a very slight change (around 0,001 – 0,004%), which is denoted by light brown colour. Some have a bigger change (around 0,164 – 0,178%). The higher changes are 1% and around 2%.

Because the rate of change of parameter is one 1%, so if the rate of change of variable is around 1 – 2%, we could say change of parameter has important effect on that variable. If the rate of change of variable is around 0,1 – 0,2%, we could say it's medium importance. If the rate of change of variable is around 0,001-0,010%, we could say it's slight or very slight importance.

In brief, we have table 2 as **a first impression** that derived from the table 3:

Change of parameter	**Effect on variable**			
	Crops produced per person per year	**Population**	**Salt concentration**	**Volume of Coastal Aquifer**
Annual food requirement per	Important	Medium	Very slight	Very slight

person per year				
Cross sectional area aquifer	No	No	Very slight	Important
Irrigation water need per meter square	No	No	Very slight	Very slight
Percentage of salt seeps down into aquifer	No	No	No	No
Reference point of salt rate	No	No	Very slight	No

Table 2: interpreting of table 3

Debrief from the first impression (table 2), we see that:

- Change in annual food requirement per person per year has:
    - Important effect on change of Crops produced per person per year. This situation is logical, because there is one constraint between food requirement and the increase of irrigated / non-irrigated land. If one person needs more food, the total food requirement increases, then more land for irrigation, then more crops produced.
    - Medium effect on change of Population. This situation sounds strange because there are no equations that connect those 2 factors. However, as we see, this effect is flat for time at 10, 20, 30, 40 and 50. This means, the high number of percentage change is only a jump from time 0 to time 10. Therefore, actually, in the current model, annual food requirement per person per year has no effect on Population. Though, this conclusion does not mean there is no relation between those 2 parameter and variable. In common sense, the average personal food requirement must have effect on the emigrants, which directly links to population. For instance, the more food people require, the more natural resources (water and land) they need. Gradually, when the natural resource reaches its limits, water and land are scarce, people must leave to another places to find food and drinking water. In brief, relation between food required, food produced, emigrants and population must be researched further.
    - Very slight effect on changes of Salt concentration and Volume of Coastal Aquifer. This situation is understandable because the increase of food requirement will lead the increase in irrigation water demand, then decrease the volume of coastal aquifer. Volume of Coastal Aquifer and Salt concentration has direct link, so effect on one factor will also mean effect on other factor.
- Change in Cross-sectional area has:
    - No effect (almost) on change of Crops produced per person per year and Population. This situation is explainable because there are no equations represent their relation. Moreover, in common sense, this situation is logical.
    - Very slight effect on change of Salt concentration. Though Cross-sectional area appears in equation to calculate the salt concentration, there are more few parameters (Porosity, Length of Aquifer, and Salt in the Aquifer). It might be the reason why the effect is almost invisible.

    - Important effect on change of Volume of Coastal Aquifer. Actually these high values do not reflect the actual situation. Because the initial value of Volume of Coastal Aquifer is changed together with change in the cross-sectional area. That is the reason why there is percentage of change of 1% right at time 0. And from that reason, in fact, this parameter has a very slight effect on Volume of Coastal Aquifer.
- Change in Irrigation water need per meter square has:
    - No effect on change in Crops produced per person per year and Population. This situation is understandable.
    - Slight effect on change in Salt concentration and Volume of Coastal Aquifer. This situation is understandable because the increase of water need per meter square will lead the increase in irrigation water demand, then decrease the volume of coastal aquifer. Volume of Coastal Aquifer and Salt concentration has direct link, so effect on one factor will also mean effect on other factor.
- Change in Percentage of Salt in the topsoil seeps down into the aquifer has NO effect on change in all 4 variables. This situation seems to be relatively illogical in the case of Crops produced per person per year. Because in common sense, salt accumulated after rain will decrease the crops yield. And if this relation (between Percentage of Salt seeps down and Crops produced) exists, the Population and Salt Concentration also involve in variation with change of Percentage of Salt seeps down. This issue must be research further.
- Change in Reference point of salt rate has NO or slight effect on change in all 4 variable. This situation is understandable because Reference point of salt rate still depends on the look-up table of Rate of Salt diffuses. If this look-up table is not good, the change in Reference point of salt rate could not present its importance in the right way.

So, **in brief**:
- Change in annual food requirement per person per year has an important effect on change of Crops produced per person per year.
- All of changes in other parameters seem lead to no change or very slight change on the 4 variable.
- There are needs to have more research on problem of
    - food required, food produced, emigrants and population
    - salt in the topsoil.
    - Look-up function of Rate of Salt diffuses.

Min - Max range of parameters	Time frame	Crops produced per person per year	Population	Salt concentration	Volume of Coastal Aquifer
MIN of Annual food requirement per person per year	0	0,000	0,000	0,000	0,000
	10	0,175	0,164	0,001	0,000
	20	2,235	0,164	0,001	0,001
	30	0,190	0,164	0,002	0,002
	40	1,984	0,164	0,003	0,002
	50	1,859	0,164	0,004	0,003
MAX of Annual food requirement per person per year	0	0,000	0,000	0,000	0,000
	10	2,426	0,178	0,000	0,000
	20	0,195	0,178	0,001	0,001
	30	2,134	0,178	0,002	0,001
	40	0,208	0,178	0,003	0,002
	50	0,215	0,178	0,004	0,003
MIN of Cross sectional area aquifer	0	0,000	0,000	0,000	1,000
	10	0,000	0,000	0,001	1,000
	20	0,000	0,000	0,002	1,001
	30	0,000	0,000	0,003	1,001
	40	0,001	0,000	0,004	1,002
	50	0,001	0,000	0,004	1,003
MAX of Cross sectional area aquifer	0	0,000	0,000	0,000	1,000
	10	0,000	0,000	0,001	1,000
	20	0,000	0,000	0,002	1,001
	30	0,000	0,000	0,003	1,001
	40	0,001	0,000	0,003	1,002
	50	0,001	0,000	0,004	1,003
MIN of Irrigation water need per	0	0,000	0,000	0,000	0,000

meter square	10	0,000	0,000	0,000	0,000
	20	0,000	0,000	0,001	0,001
	30	0,000	0,000	0,001	0,001
	40	0,000	0,000	0,001	0,001
	50	0,000	0,000	0,002	0,002
MAX of Irrigation water need per meter square	0	0,000	0,000	0,000	0,000
	10	0,000	0,000	0,000	0,000
	20	0,000	0,000	0,001	0,001
	30	0,000	0,000	0,001	0,001
	40	0,000	0,000	0,001	0,001
	50	0,000	0,000	0,002	0,002
MIN of Percentage of salt in the topsoil seeps down into the aquifer	0	0,000	0,000	0,000	0,000
	10	0,000	0,000	0,000	0,000
	20	0,000	0,000	0,000	0,000
	30	0,000	0,000	0,000	0,000
	40	0,000	0,000	0,000	0,000
	50	0,000	0,000	0,000	0,000
MAX of Percentage of salt in the topsoil seeps down into the aquifer	0	0,000	0,000	0,000	0,000
	10	0,000	0,000	0,000	0,000
	20	0,000	0,000	0,000	0,000
	30	0,000	0,000	0,000	0,000
	40	0,000	0,000	0,000	0,000
	50	0,000	0,000	0,000	0,000
MIN of Reference point of salt rate	0	0,000	0,000	0,000	0,000
	10	0,000	0,000	0,001	0,000
	20	0,000	0,000	0,002	0,000
	30	0,000	0,000	0,003	0,000
	40	0,001	0,000	0,004	0,000
	50	0,001	0,000	0,005	0,000
MAX of Reference point of salt	0	0,000	0,000	0,000	0,000

rate	10	0,000	0,000	0,001	0,000
	20	0,000	0,000	0,002	0,000
	30	0,000	0,000	0,003	0,000
	40	0,001	0,000	0,004	0,000
	50	0,001	0,000	0,000	0,000

Table 3

2. Functions versus parameters

For the most sensitive rates investigate whether this sensitivity lies in the single valued parameters or in the (table) functions. For at least one (table) function, explore how sensitive your model is to changing the shape of the function. Discuss briefly.

Look-up function of **Rate of salt diffuses**

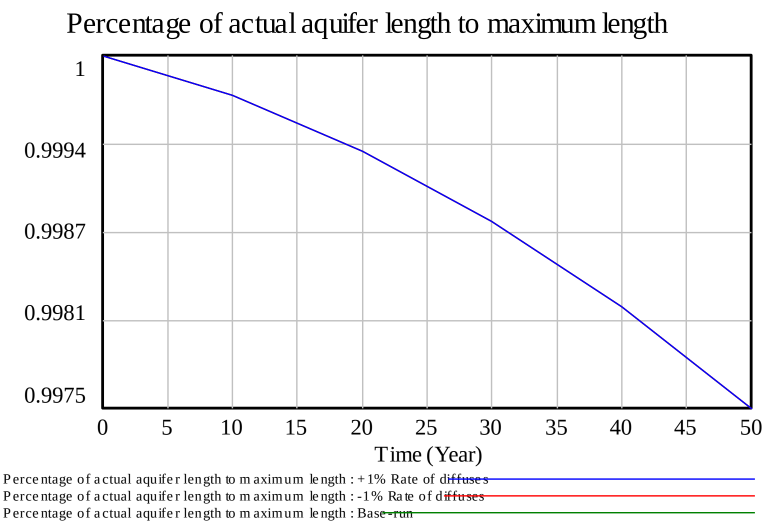
- x-axis (Input): Length of aquifer/Max length of aquifer
- y-axis (Output): Multiple-time of rate of salt diffuses (with Reference point of salt rate of 800mg/m2/year)

Input	**Output**		
	Original data	**-1% change**	**+1% change**
0	15	14,85	15,15
0,25	10	9,9	10,1
0,5	5	4,95	5,05
0,75	1	0,99	1,01
1	0,5	0,495	0,505

Results of rate sensitivity analysis in "Rate of salt diffuses" to 4 variables "Crops produced per person per year", "Population", "Salt concentration" and "Volume of Coastal Aquifer".

Time (Year)	0	10	20	30	40	50
Selected Variables Runs:	+1% Rate of diffuses		-1% Rate of diffuses		Base-run	
Crops produced per person per year	69.16	96.01	97.39	96.40	96.96	97.10
: -1% Rate of diffuses	69.16	96.01	97.39	96.40	96.96	97.10
: Base-run	69.16	96.01	97.39	96.40	96.96	97.10
Population	443,992	460,109	483,692	508,483	534,546	561,943
: -1% Rate of diffuses	443,992	460,109	483,692	508,483	534,546	561,943
: Base-run	443,992	460,109	483,692	508,483	534,546	561,943
Salt concentration	100,000	100,002	100,013	100,028	100,047	100,071
: -1% Rate of diffuses	100,000	100,000	100,009	100,022	100,039	100,061
: Base-run	100,000	100,001	100,011	100,025	100,043	100,066
Volume of Coastal Aquifer	146 B	145.96 B	145.90 B	145.83 B	145.74 B	145.63 B
: -1% Rate of diffuses	146 B	145.96 B	145.90 B	145.83 B	145.74 B	145.63 B
: Base-run	146 B	145.96 B	145.90 B	145.83 B	145.74 B	145.63 B

According to the above result, the rate change of Rate of diffuses only have slight impacts the Salt concentration. This is because the Input (Length of aquifer/Max length of aquifer) does not vary too much. The model run shows that, the actual Input of this look-up table only ranges within (0.9975 – 1) in period of 50 years. The length of aquifer decreases very small, from 8000m inland to 7980m.



3. Comparison with normalized sensitivity analysis

Compare and contrast your results with the outcomes of a normalized sensitivity analysis of the involved parameters.

"Because each physical parameter usually has its own unit, a comparison among different parameters […] is very difficult and potentially could be misleading. In order to remove the dimensional effect, we define a normalized sensitivity."(Zhang et al., 2007)

Let's take a simple equation of *Total Crops Produced* as the Variable, and *Annual Food Requirement Per Person per year* as Parameter. Population at year = 1 is 100.000 with an annual increase of 5%.

$$TotalCropsProduced = Population \times AnnualFoodRequirementPerPeson$$

Then for the Rate Sensitivity Analysis, we calculate by the following formula:

$$S_R = \frac{TotalCropsProduced - TotalCropsProduced_{year0}}{TotalCropsProduced_{year0}}$$

$TotalCropsProduced_{year0}$ is the reference point.

So Normalized Sensitivity (Sn) of parameter Annual Food Requirement Per Person (per year) to variable Total Crops Produced is:

$$S_n = \frac{AnnualFoodRequirementPerPerson}{TotalCropsProduced} \times \frac{\delta TotalCropsProduced}{\delta AnnualFoodRequirementPerPerson}$$

By the results of table 4, we see that there is no difference between Rate Sensitivity and Normalized Sensitivity in this case.

However, when trying to make the case more complex, for example:

(1) Put an constant in equation of Total Crops Produced: Table 5

$$TotalCropsProduced = Population \times AnnualFoodRequirementPerPeson + \boldsymbol{Constant}$$

Those 2 sensitivities are still the same.

(2) Increase the power of Annual Food Requirement Per Person to 2 (instead of 1): Table 6

$$TotalCropsProduced = Population \times AnnualFoodRequirementPerPeson^2$$

Those 2 sensitivities became slight different.

In conclusion: depends on the complexity of equation, the rate sensitivity analysis and normalized sensitivity analysis could be the same or different. Though we could not say which one is better, as its definition, the normalized sensitivity analysis should us the percentage change of the targeting variable to the percentage change of parameters without dimension concern whereas rate sensitivity does not.

Year	Population	Parameter	Variable (REF)	Parameter + 1%	Variable at (Parameter + 1%)	Rate sensitivity analysis	Normalized sensitivity analysis
1	100.000	80	8.000.000	80,8	8.080.000	1,000	1,000
2	105.000	80	8.400.000	80,8	8.484.000	1,000	1,000
3	110.250	80	8.820.000	80,8	8.908.200	1,000	1,000
4	115.763	80	9.261.000	80,8	9.353.610	1,000	1,000
5	121.551	80	9.724.050	80,8	9.821.291	1,000	1,000

Table 4: *Variable* = Population x *Parameter*

Year	Population	Parameter	Variable (ref)	Parameter + 1%	Variable at (Parameter + 1%)	Rate sensitivity analysis	Normalized sensitivity analysis
1	100.000	80	8.008.000	80,8	8.088.000	0,999	0,999
2	105.000	80	8.408.000	80,8	8.492.000	0,999	0,999
3	110.250	80	8.828.000	80,8	8.916.200	0,999	0,999
4	115.763	80	9.269.000	80,8	9.361.610	0,999	0,999
5	121.551	80	9.732.050	80,8	9.829.291	0,999	0,999

Table 5: *Variable* = Population x *Parameter* + Constant

Year	Population	Parameter	Variable (ref)	Parameter + 1%	Variable at (Parameter + 1%)	Rate sensitivity analysis	Normalized sensitivity analysis
1	100.000	80	640.000.000	80,8	652.864.000	2,010	1,990
2	105.000	80	672.000.000	80,8	685.507.200	2,010	1,990
3	110.250	80	705.600.000	80,8	719.782.560	2,010	1,990
4	115.763	80	740.880.000	80,8	755.771.688	2,010	1,990
5	121.551	80	777.924.000	80,8	793.560.272	2,010	1,990

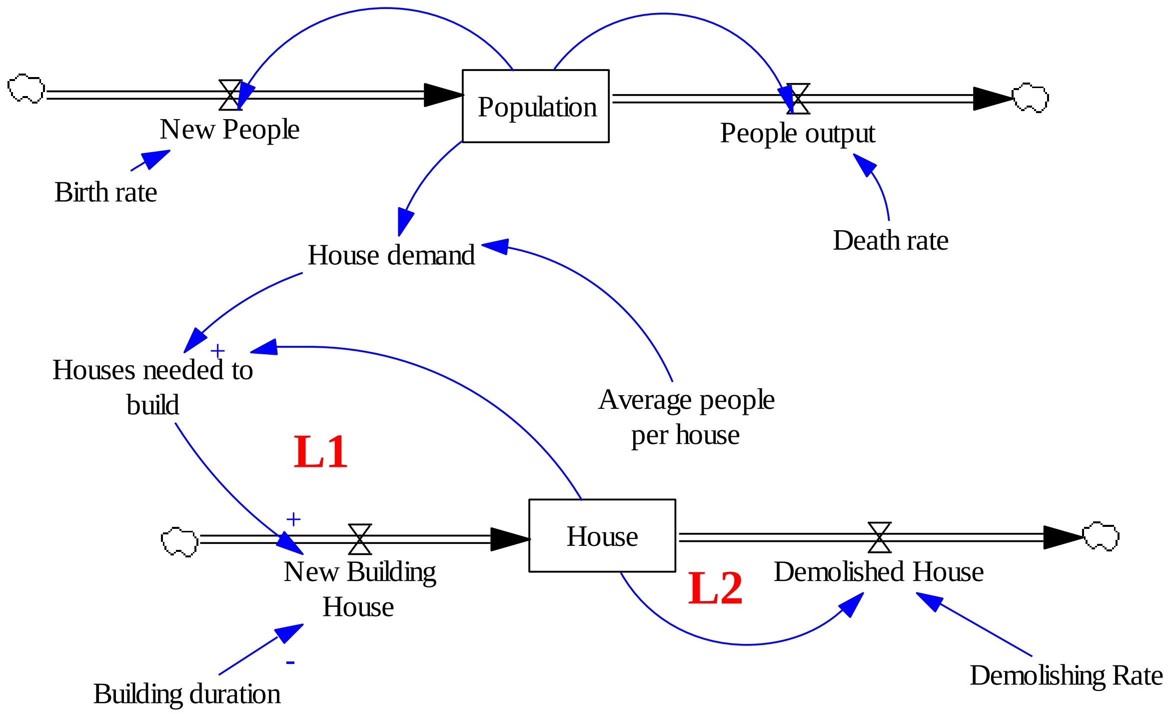
Table 6: *Variable* = Population x *Parameter*^2

Exercise 2: Model behavioural analysis

In the lecture on model behavioural analysis, two methods of analysis are discussed. For this assignment you are asked to apply Ford's behavioural approach to the Community Aquifer model.

1. Formulate a dynamic hypothesis of your model

Using your knowledge from building and experimenting on your model, formulate an initial dynamic hypothesis for (part of) your model.



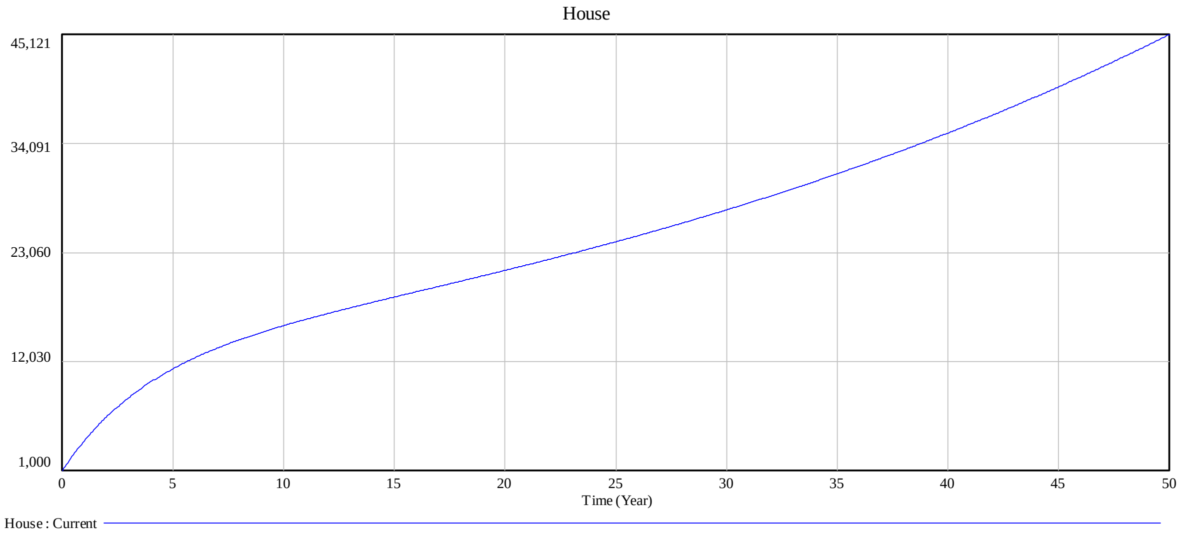
In overall, the HOUSE variable has input and output flow which impact the value of their variable stock. Those input (New Building House) and output (Demolished House) must have the equal importance in House final result. If the input is superior to the output, the House value will increase exponentially. If the input is equal to the output, the House value will be stable. If the output is superior to the input, the House value will decrease exponentially.

<u>Step 1</u>: POPULATION is selected as the variable of interest. The behaviour of the variable of interest and atomic behaviour indicator over 10 years are shown as the following figure:

<u>Step 2</u>: The behavior pattern shows that:

- from year 0 – year 16 (approximately), the behavior atom is logarithmic
- from year 16– year 50, the behavior atom is exponential

House Demand	= Population/Average people per house	(houses)
House Shortage	= (MAX (House Demand, House) – House) / House Demand	
Average people per house = 7		(people/house)
Building house	= House Shortage / Building duration	(house/year)
Building duration	= 5	(year)
Birthrate	= Look-up function of House Shortage	(%/year)



Step 3: Feedback Loop 1 and 2 are selected as the candidate loop. However, we will do activation and deactivation to each group turn by turn, to isolate the impact of each group on the other.

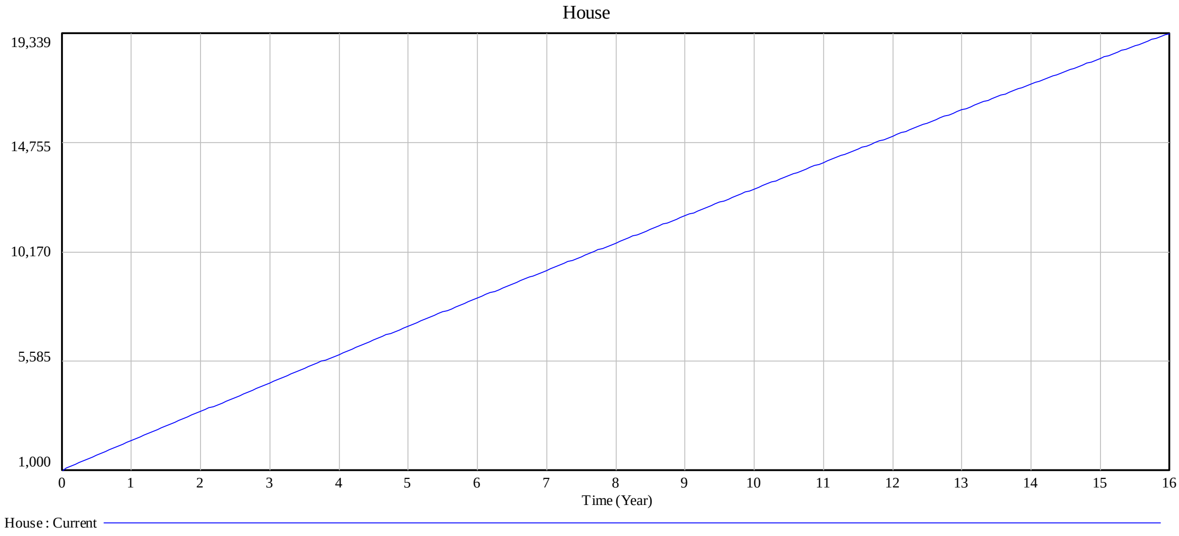
Step 4: **Deactivate** the feedback loop L1 by severing the causal link between House - House Needed to build – New House. This could be done by changing the equation of New House from:

New House = House Needed to build / Building duration

To:

New House = 5000 / Building duration

This change of above equation results in a change in the behavior pattern of Houses (between year 0 and 16), which now becomes linear (though approximately, because theoretically it must be very slightly logarithmic). So, we could conclude that feedback loop 1 is a dominant loop.

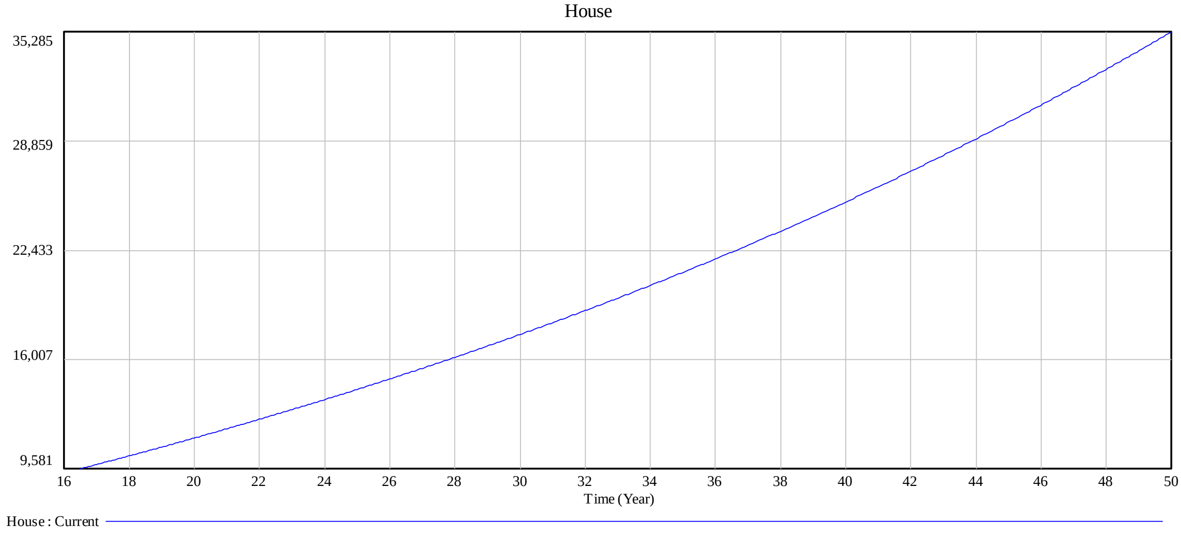


Step 5: **Reactivate** the feedback loop 1 and **deactivate** the feedback loop 2 as the candidate loop. This could be done by changing the equation of Demolishing House

from:

Demolishing House = House / Demolishing Rate to:

Demolishing House = 2500



This change of above equation results NO change in the behavior pattern of Houses (between year 16 and 50), which still remain exponential. So, we could conclude that feedback loop 2 is NOT a dominant loop.

Step 6: In conclusion, in the overall behavior pattern of HOUSE variable, the feedback loop 1 has a dominant impact, whereas the feedback loop 2 has not. These results do not relate directly to the dynamic hypothesis, but give new information in the behavior of the House.

However, this method still has some confusing points, such as:

(1) At step 4, in theory, it needs to find a control variable for each loop which does not appear in the equation of other loops. But in fact, it is difficult to define what is the control variable in a complex equation, especially when that equation is connected to many other loops.

(2) At step 3, in theory, it needs to choose some feedback loops to analyze. This could be simple if there is a few feedback loops in the model. But when there are too many overlap feedback loops, selecting the right loops becomes not-easy task.

Appendix

#	Parameter	Group	Uncertainty	Reason	Importance	Reason
	Initial population					
1	Birth Rate	Population	Low / High	This information is extracted from the statistical data of national or regional agencies. In theory, this data is reliable because of its pure statistics. However, depend on the development level of targeting country, the confidence on the data accuracy could be low or high.	High	Population is one of most important factor in the model, which impacts all other sub-model since it is the input data. Therefore, the unique parameter that changes the increase of population must have an important role.
2	Death Rate	Population	Low / High	As above	High	As above, but from viewpoint of "decrease of population"
3	Delay time before leaving country	Population	High	This information is totally based on the assumption of modellers. There are many reasons leading to the abandonment of people (food shortage, water shortage, low living standards, civil conflicts, war, etc.). So it is very hard to make a precise quantitative relationship of people leaving with other factors in the model.	High	As above, but from viewpoint of "decrease of population"
4	Annual food requirement per person per year		High	It is hard to say what standard of average amount of food people need per day. It really depends on the location, habit, level of development, or even the proportion of children, young people, and old people in that area.	High	A very quick calculation of food people need and food produced (with all of initial values) shows that the production is bigger than demand, and this situation seems to exist for long. However, because this factor will affect the total food requirement, then possible impacts the food shortage.

						Therefore, I classify it in group of high importance.
5	Average people per house	Land use	Medium	This data depends on the family structure of local area which could be extracted from national statistics. If the model covers a large area of country, due to the difference between city and countryside, this data could be even more uncertain. Therefore, because of its nature of "varying widely", this information should be categorized in medium uncertainty group.	Low	Those 3 parameters in group "Land use" are used to calculate the total housing and business land. However, thanks to some first results, the proportion of housing and business land compared to total land is small. People seem always have enough land for building new houses or business building. Therefore, the importance of those 3 parameters in model is valued at "low".
6	Average area per house	Land use	Medium	As above	Low	
7	Average area per working person	Land use	High	As above, but even higher uncertainty because this is obviously sort of "imaginary" or "estimated" data.	Low	
8	Average River Flow		Low	In theory, because many agencies or association do the task of measure and recording the river flows, this data could be get with relative high degree of accuracy. Moreover, in case of lacking data, an estimation based on the available data of other rivers with the same annual characteristics could be possible, though it takes high risks of error.	High / Medium	
9	Upstream extraction		High	This parameter is highly estimated, so the uncertainty is high. However, like other parameters, applying one value of climate to a large area could cause a big error.	High / Medium	

10	Rain fall mm/year		Low	It is able to collect this data from national climatic data centre with a relative high degree of accuracy. However, like other parameters, applying one value of climate to a large area could cause a big error. Moreover, in case of lacking data (some countries or regions do not have it), an estimation based on the available data of other countries or regions could be possible, though it takes high risks of error.	High / Medium	
11	Total raining area		Low	This is pure geographic data, not difficult to get a relatively exact value. However, it must be sure about the impact area in this model when specifying the total raining area.	High / Medium	
12	Rain lost		Low / Medium	Same as the above climatology parameters, it is possible to get this data from some climate centres (if available). Searching the estimation of this data shows the large range of value in different countries (60 - 87%).	High / Medium	
13	Percentage of remaining irrigation water		Medium / High		High / Medium	
13	Cross sectional area aquifer		High / Very high	Because of the big magnitude of this factor, and of difficult in measuring it, this data should be considered as high or high uncertainty.	High / Very high	

14	Porosity		Medium / High	Though this data does not have a big magnitude of value, it's still doubted about its accuracy. Is it possible to measure the porosity of one large area? According to some documents, this data could range widely from 5% - 50%.	High / Very high	
15	Average water use per person per year		High	This data could be a bit similar to average food requirement per person. The website http://chartsbin.com/view/1455 has some numbers for different countries, however, there is no statement about the information source, methodology or accuracy.	Medium / High	
16	Average water use per person in industry per year		High	This parameter is highly estimated, so the uncertainty is high.	Low / Medium	
17	Irrigation water need per meter square		High		High / Very high	
18	Percentage of salt in the topsoil seeps down into the aquifer		High		High	
19	Reference point of salt rate		High		High	
20	Salt effect multiplier		High		High	
21	Yield or irrigated crops		Medium		Low / Medium	

22	Yield of non-irrigated crops		Medium		Low / Medium	
23	Time of business expanding	Land use	High		Low / Medium	
24	Time of business demolishing	Land use	High		Low / Medium	
25	Growth speed of non-irrigated land	Land use	High		Low / Medium	
26	Growth speed of irrigated land	Land use	High		Low / Medium	
27	Time of converting	Land use	High		Low / Medium	

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