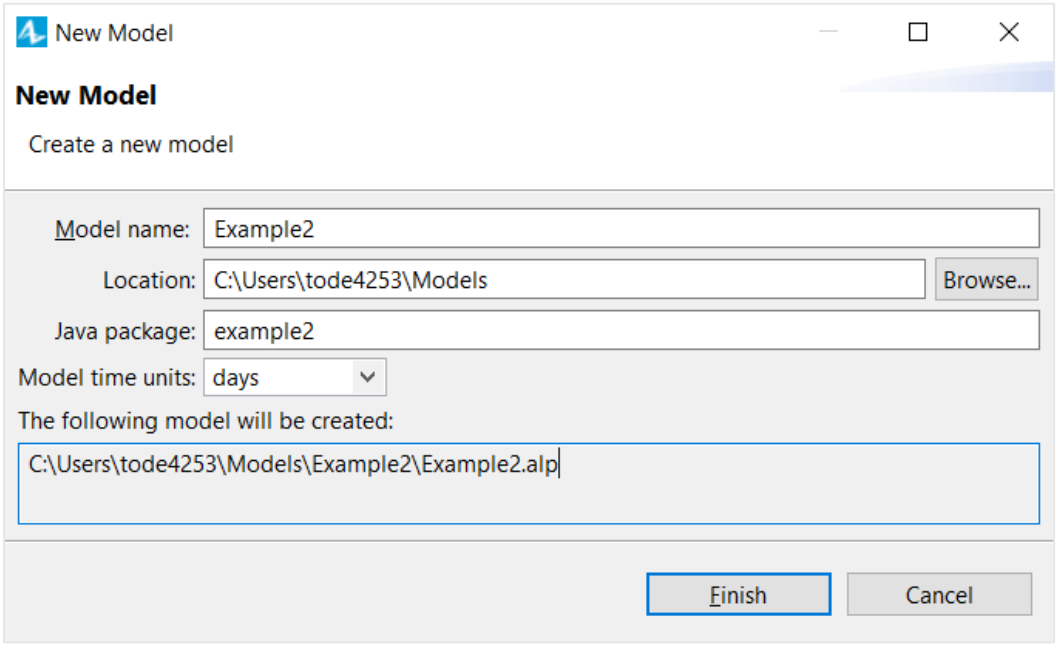
AnyLogic – Tutorial 02

System Dynamics and Urban Model

1. System Dynamics (SD)

System Dynamics is used for long-term, strategic models. SD models represent people, products, events, and other discrete items by their quantities. For this, conditions (stocks) and their changes (flows) must be described. Stocks are usually expressed in quantities such as people, inventory levels, money, or knowledge, while flows are typically measurements of quantities in a given time period such as clients per month or dollars per year. SD can be combined with discrete event and agent based modeling.

2. Getting started



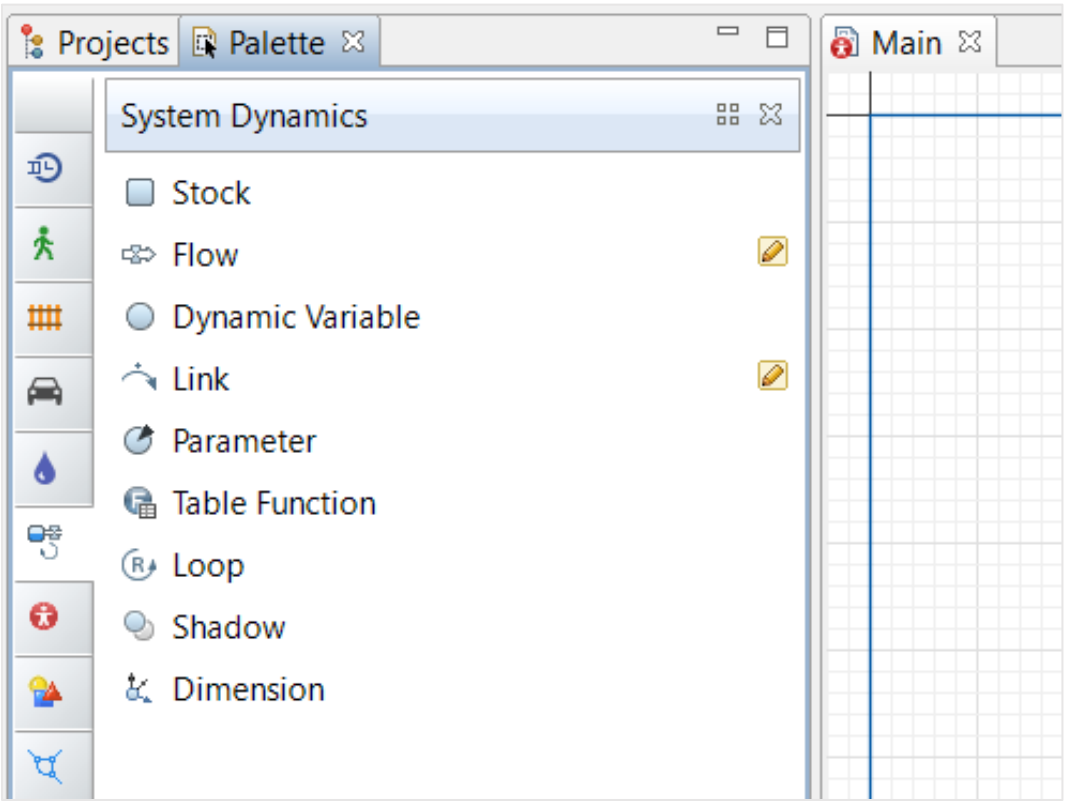
New model

Close the Welcome page.

Click *File* > *New* > *Model*.

Click *Finish*.

3. System Dynamics - Palette



SD Palette

Open the Palette System Dynamics by using the Vertical Navigationbar.

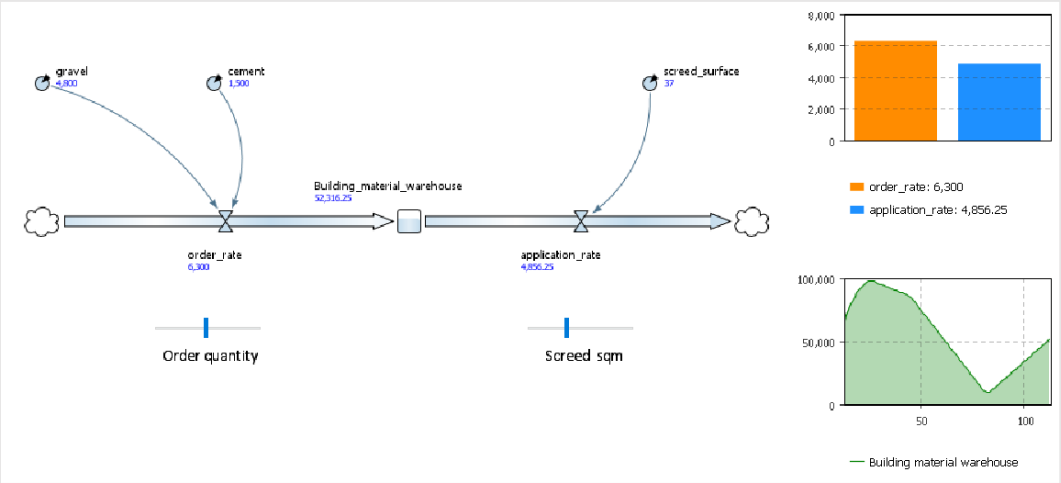
Basic Elements

Stock	real-world quantities of people, water, money, etc.
Flow	define rate of change.
Dynamic Variable	commonly to serve inputs or store outputs to/from stocks or flows.
Link	Influence by Paramter, Dynamic Variable (Auxiliary Variable), etc.
Parameter	commonly to serve inputs to stocks or flows.

4. SD - Example 2

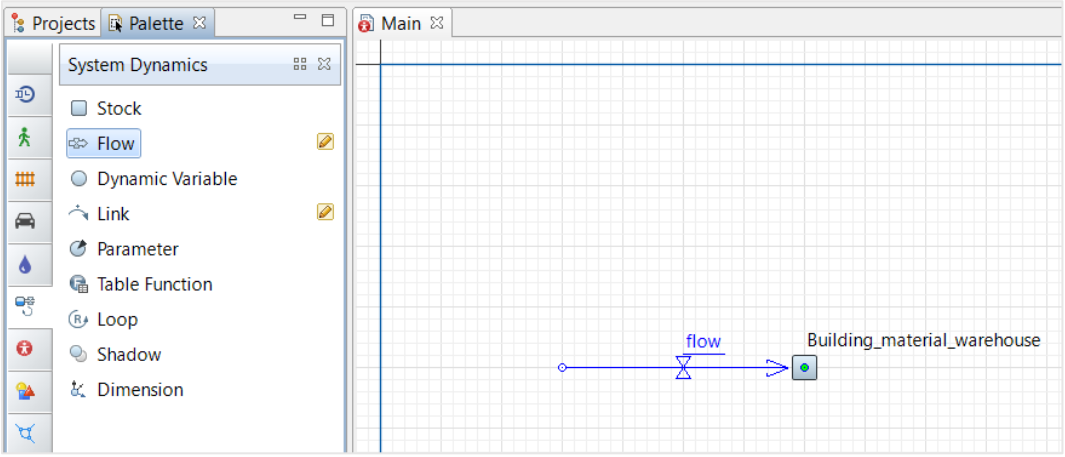
You would like to apply 5 cm of cement screed on a surface and would like to know how much gravel and cement you will need to hold in relation to the size of the building material store.

Cement screed consists of gravel, cement and water. Water is ready in the course of the construction site. The mixing ratio of gravel to cement is 3.2:1. For a square meter of applied cement screed you need about 100 kg of gravel and 31.25 kg of cement.



Simulation

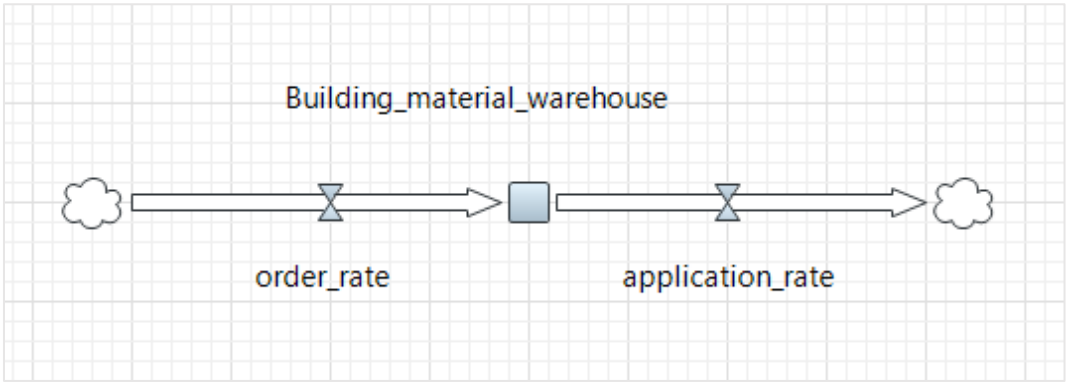
Create Stock and Flows



Create Stock and Flows

Drag a Stock element onto the canvas and name it *Building_material_warehouse*.

Drag a Flow element onto the canvas and connect it with the Stock. A green dot appears in the Stock element when the connection is made. Name the flow element *order_rate*.

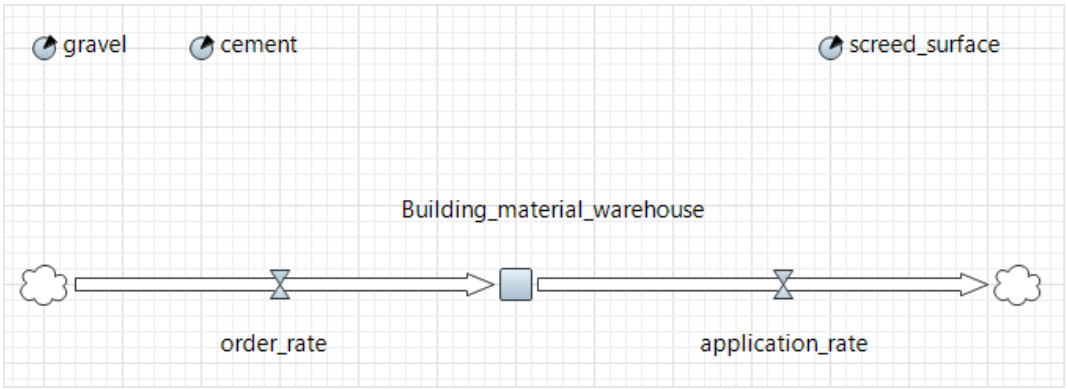


Stock and Flows

Drag a Flow element onto the canvas and connect it with the Stock. Name the flow element *application_rate*.

The identifiers can be moved on the canvas after selecting the associated element.

Create Parameters



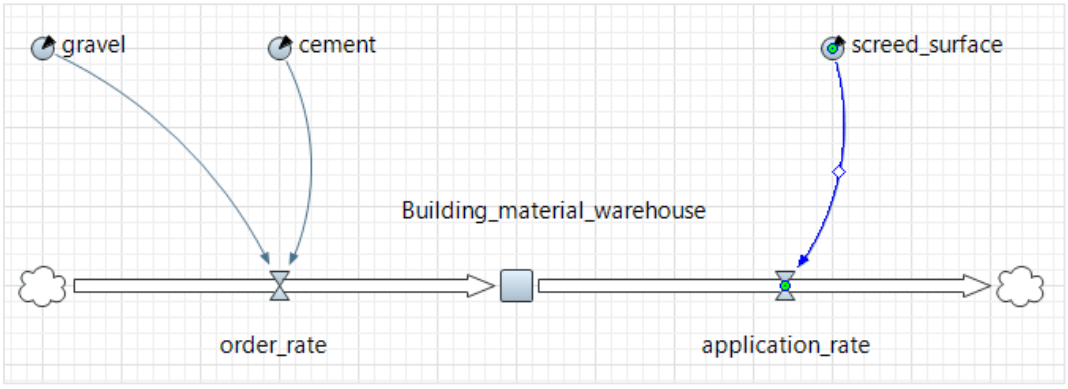
Create Parameters

Drag a Parameter onto the canvas and name it *gravel*.

Drag a Parameter onto the canvas and name it *cement*.

Drag a Parameter onto the canvas and name it *screed_surface*.

Link Parameters and Flows



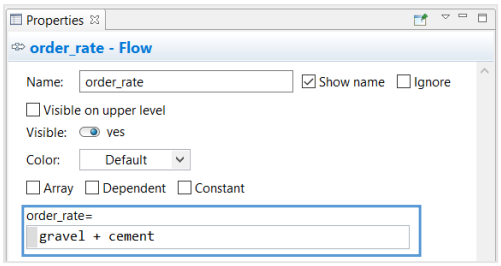
Create Links

Drag a Link onto the canvas and connect the Parameter *gravel* with the Flow *order_rate*. Consider a working connection.

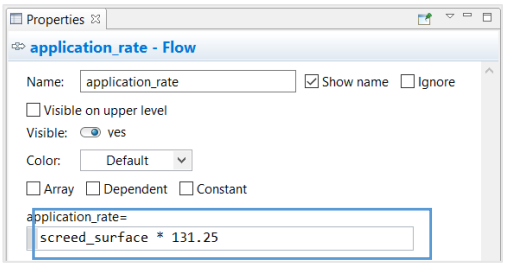
Drag a Link onto the canvas and connect the Parameter *cement* with the Flow *order_rate*.

Drag a Link onto the canvas and connect the Parameter *screed_surface* with the Flow *application_rate*.

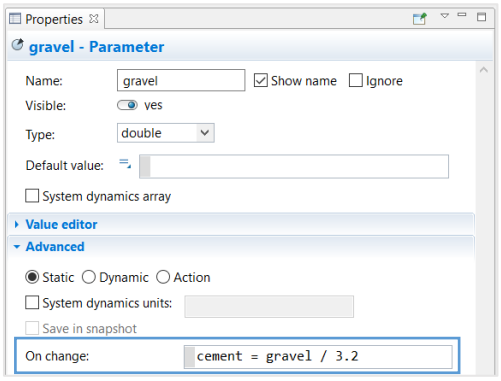
Edit Properties



Properties order_rate

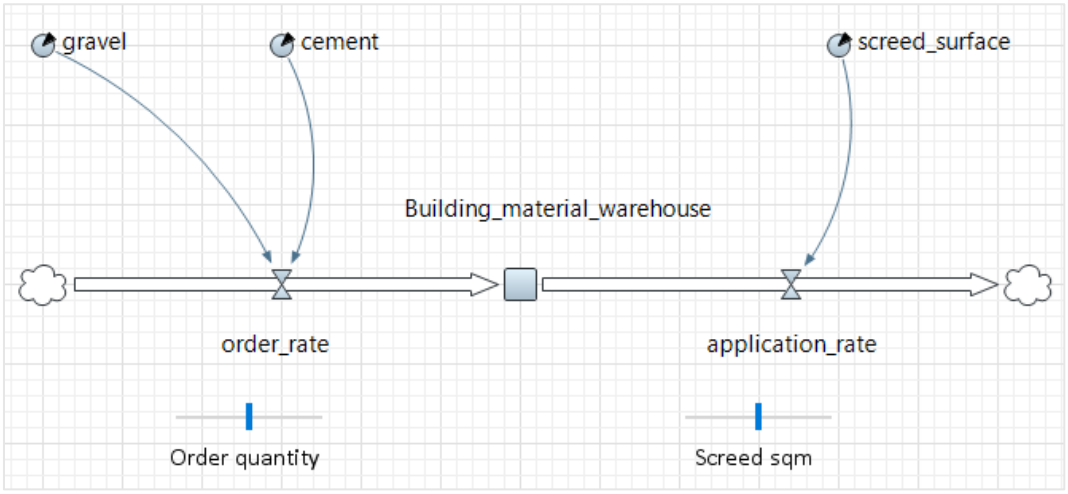


Properties application_rate



Properties gravel

Create Sliders and Text-Elements



Create Sliders and Text-Elements

Open the Palette *Controls*.

Drag a Slider onto the canvas and name it *quantity_gravel*.

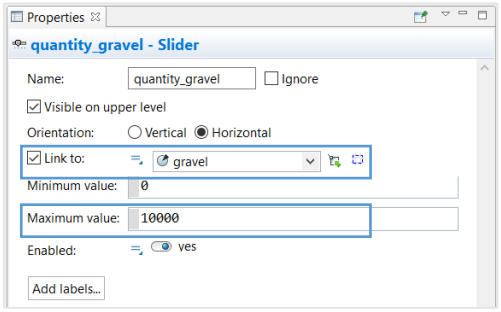
Drag a Slider onto the canvas and name it *quantity_screed*.

Open the Palette *Presentation*.

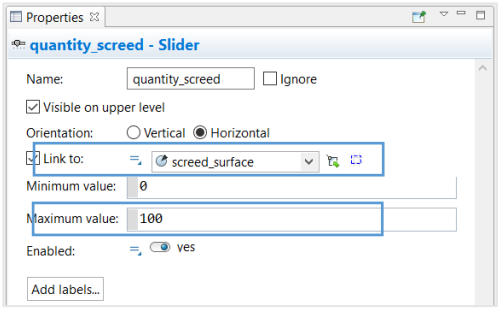
Drag a Text-Element onto the canvas and name it *txt_quantity_gravel*. Edit the Text property to *Order quantity* and edit the Appearance Properties as you like.

Drag a Text-Element onto the canvas and name it *txt_quantity_screed*. Edit the Text property to *Screed sqm* and edit the Appearance Properties as you like.

Edit Properties

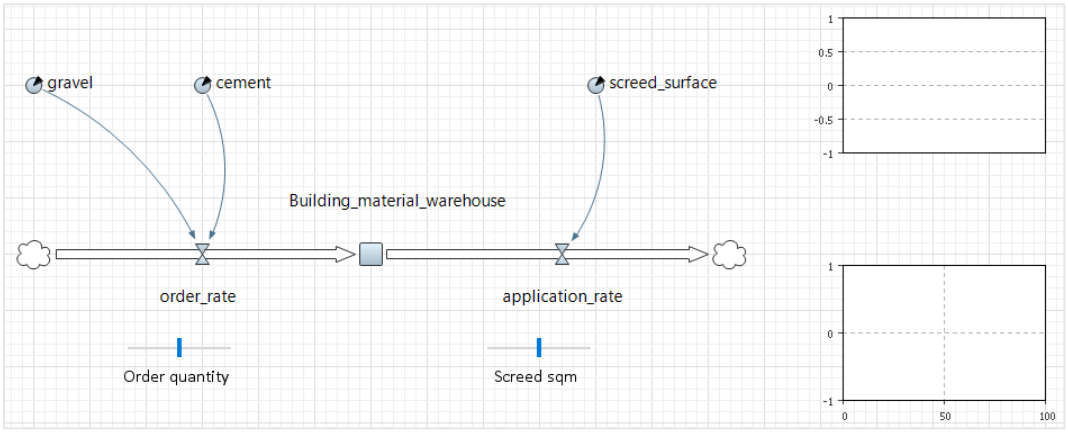


Properties quantity_gravel



Properties quantity_screed

Create Bar Chart and Time Plot



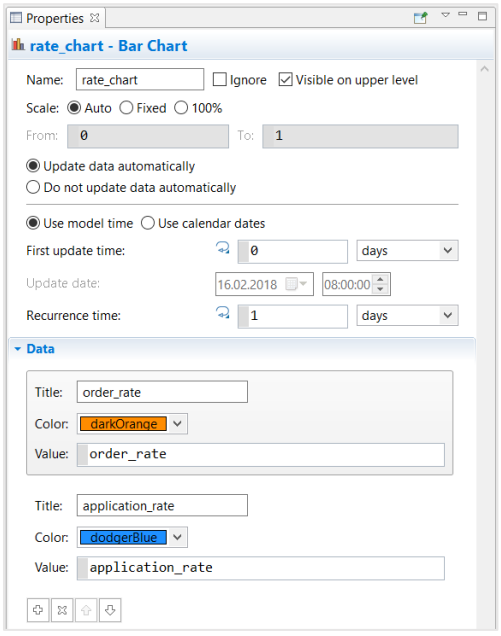
Create Bar Chart and Time Plot

Open the Palette *Analysis*.

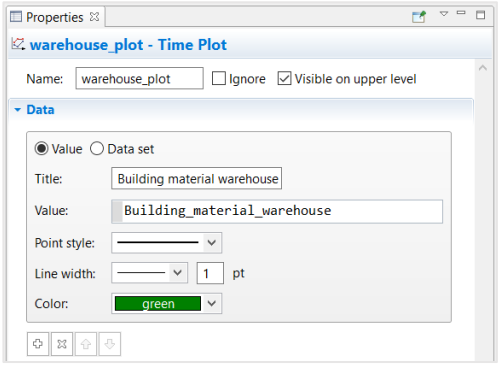
Drag a Bar Chart onto the canvas and name it *rate_chart*.

Drag a Time Plot onto the canvas and name it *warehouse_plot*.

Edit Properties



Properties Bar Chart



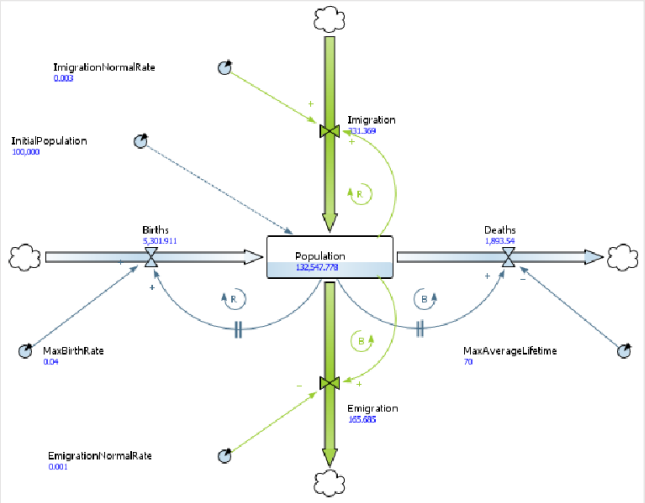
Properties Time Plot

Run the model.

5. Urban Model – Population - Exercise 2

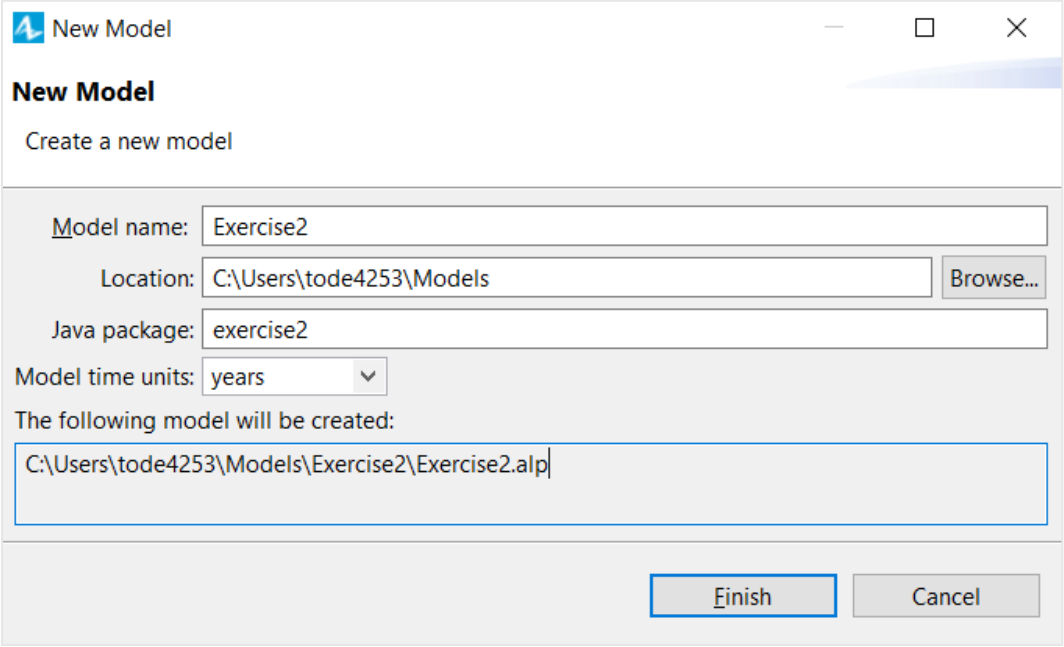
Population growth describes the evolution of the number of inhabitants on a given area. It results from the difference between the birth rate and the mortality rate, known as natural population growth. Added to this is the migration balance. This results from the difference between inflows and outflows across the territorial border.

Model population growth using SD. Take over the influencing variables from the given description.



Simulation

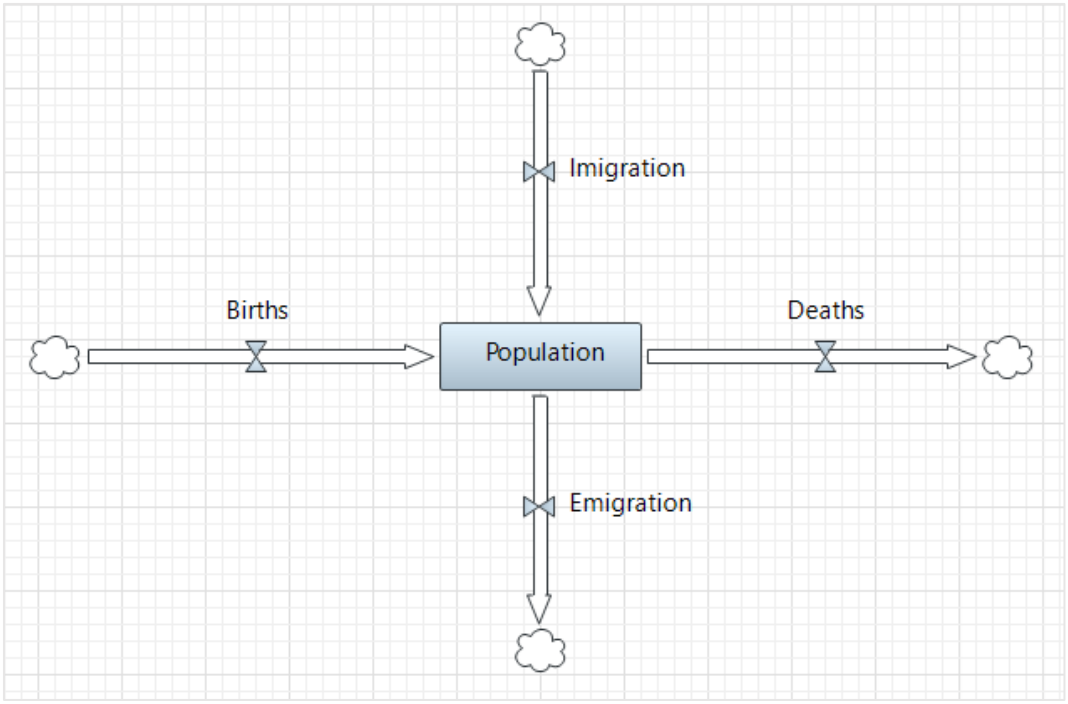
Getting started



New model

Create a new model.

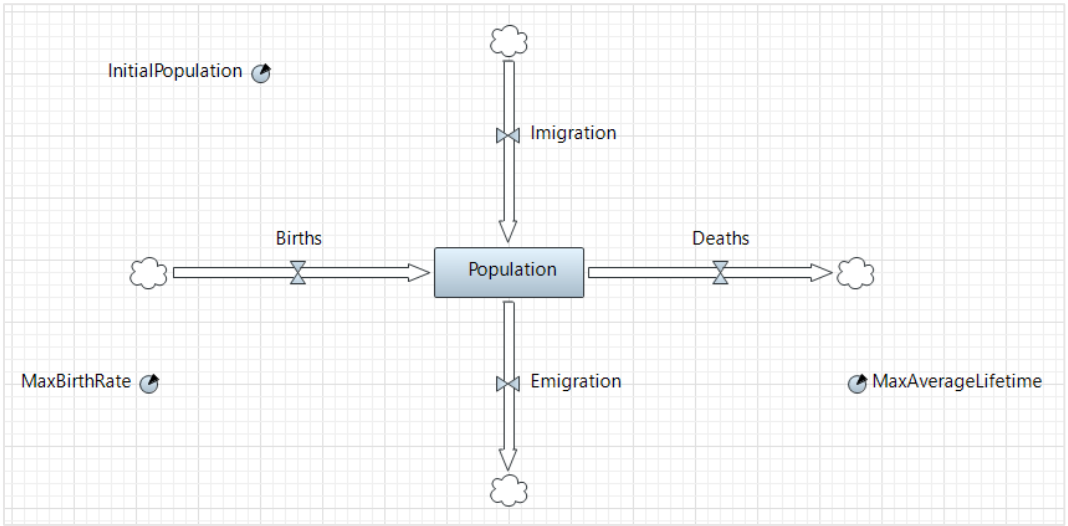
Create Stock and Flows



Stock and Flows

Create Stock and Flows.

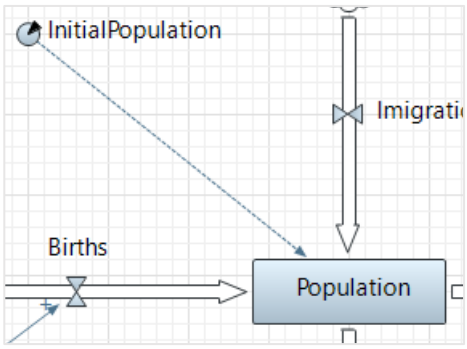
Create Parameters



Create Parameters

Create the Parameters *InitialPopulation*, *MaxBirthRate* and *MaxAverageLifetime*.

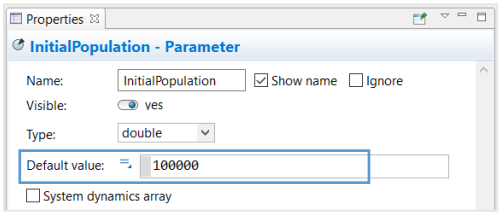
Link Parameters



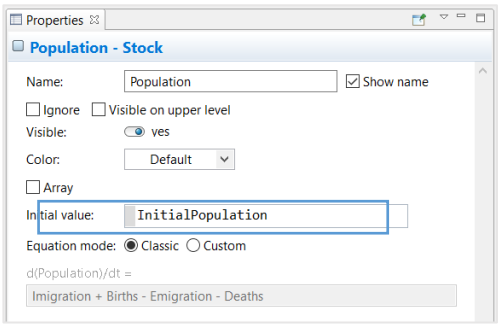
Link InitialPopulation / Population

Create a link between the Parameter *InitialPopulation* and the Stock *Population*.

Edit the following Properties.



Properties InitialPopulation



Properties Population

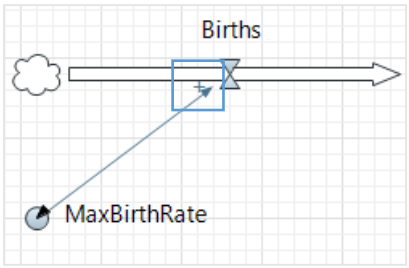
Links may have a polarity. You can choose a polarity in the Link properties, default is None.

Basic Polarity

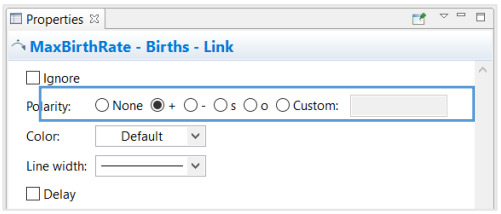
None default.

+ the connected nodes change the value in the same direction. If the start node decreases, the end node will follow.

- the connected nodes change the value in the opposite direction. If the start node decreases, the end node increases.



Link MaxBirthRate / Births

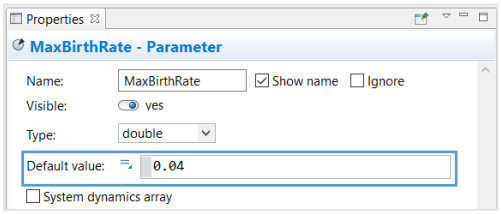


Properties Link MaxBirthRate / Births

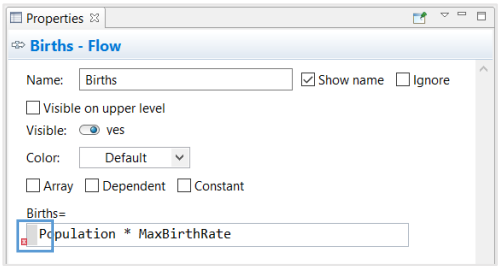
The Birth rate increases, so the total Birth increases as well.

Create a positive link between the Parameter *MaxBirthRate* and the Flow *Births*.

Edit the following Properties.

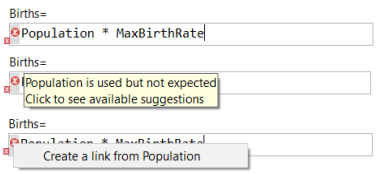


Properties MaxBirthRate

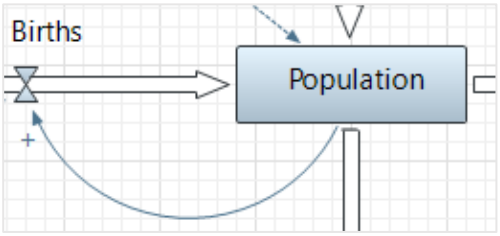


Properties Births

After the property has been adjusted, an error message appears because *Population* has not yet been connected to *Births* in the graphical Editor.

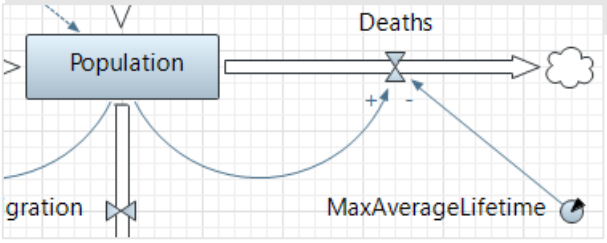


Error handling



Link Population / Births

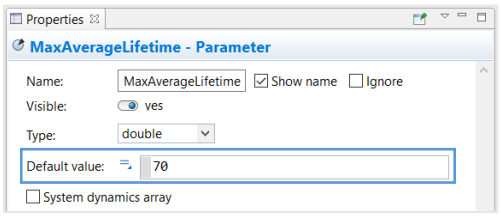
Click the Error icon to create a link between *Population* and *Births*. Then change the polarity to positive.



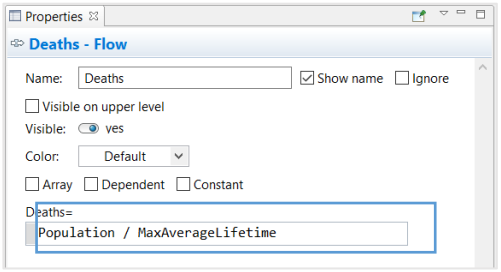
Create a negative link between the Parameter *MaxAverageLifetime* and the Flow *Deaths*.

Create a positive link between the Stock *Population* and the Flow *Deaths*.

Edit the following Properties.



Properties MaxAverageLifetime



Properties Deaths

Create Feedback loops

Loops are graphical identifier to show information. They help other users to understand the stock and flow diagram's influences and causal dependencies. Loops have a label that describes the loops meaning and an arrow that shows the loops direction.

Feedback Loops

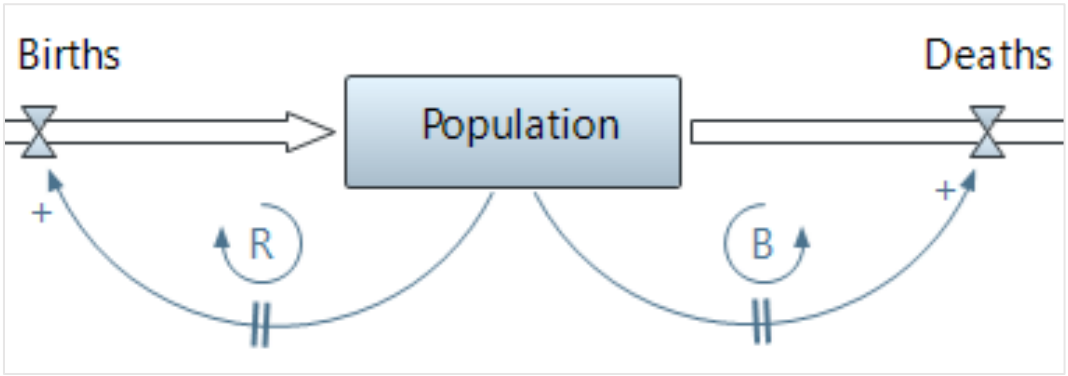
Loops are either *reinforcing* or *balancing*

reinforcing loop (R) - can describe growth and decline
- have an even or zero number of negative links

balancing loop (B) - they bring something to a desired state and stabilizing it
- have an uneven number of negative links

In our example, a larger population leads to more births and more deaths. Births increase the population, deaths reduce the population.

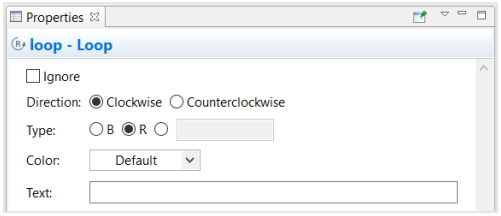
The resulting increase in births and deaths occurs with a delay. People can not have children from the day they are born and people have an average life expectancy. Delays are indicated in a link with a double line.[3]



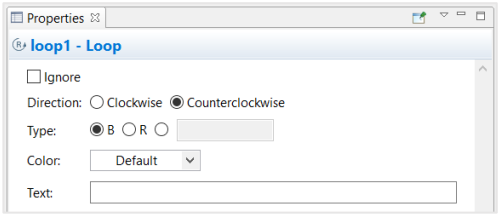
Link with Delay

Drag two Loop elements onto the canvas.

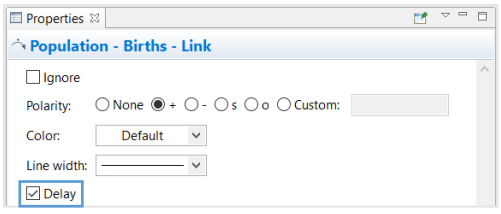
Edit the following Properties.



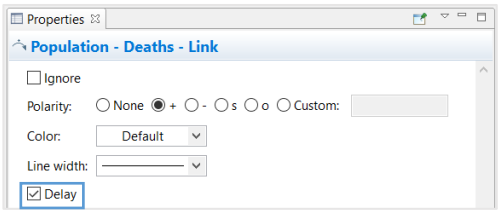
Properties reinforcing loop



Properties balancing loop



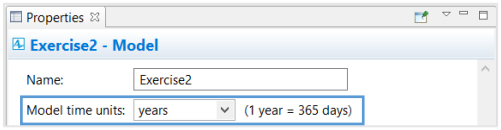
Properties link births, delay



Properties link deaths, delay

Simulation - Model time

Before we start the simulation we should adjust the time unit as well as the simulation duration. When you created the model, you have already defined a *model time unit*. This setting can be adjusted later.

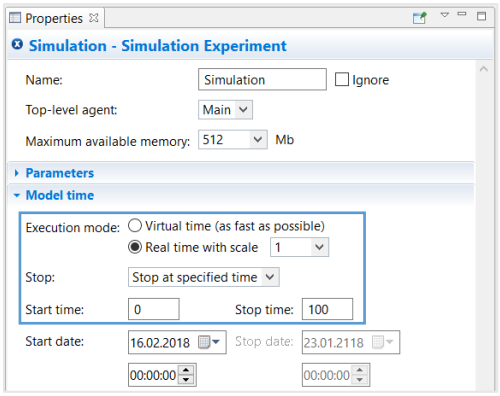


Properties Model, Model time units

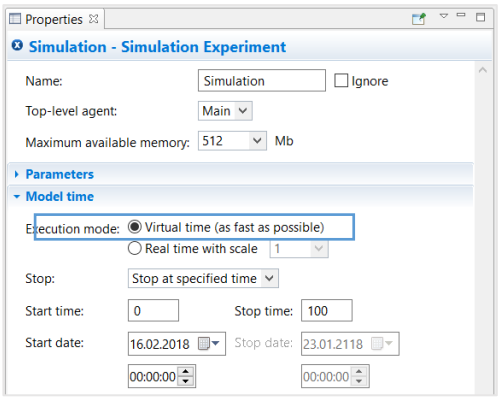
Open the Project View.

Click the modelname *Exercise2* at the top of the tree structure.
Model time units are displayed in the Properties View.
Choose *years*.

By default, AnyLogic model runs in a *Real time with scale* mode. In our case, one model year per second.



Simulation Real time with scale



Simulation Virtual time

Statusbar

Click *Simulation: Main* in the tree structure of the Projects View.

Edit the *Execution mode* to *Real time with scale 1*.

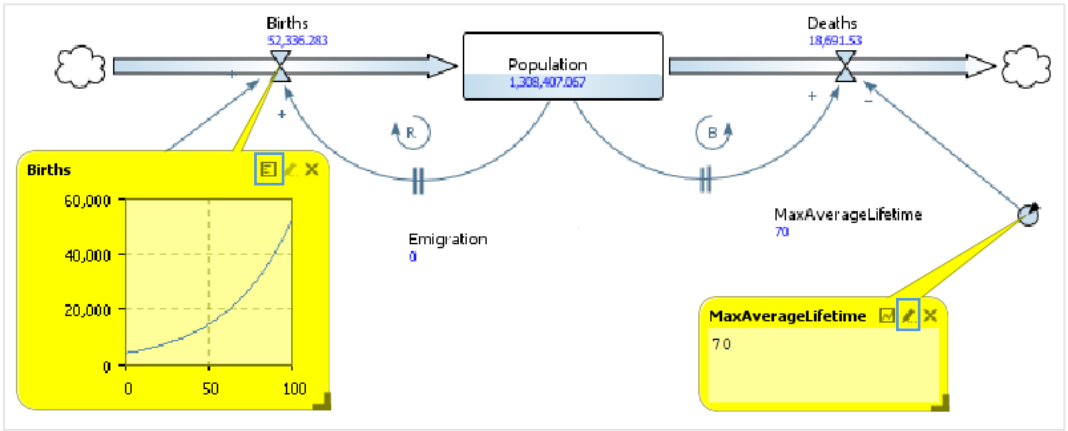
Edit the *Stop time* to 100.

Run the model. The model will run 100 seconds for 100 years. Check the Statusbar.

Alternatively, you can also choose the *Virtual time*, then you get the result immediately.

Inspect Window

In Example 2 you have permanently installed two diagrams in a simulation. There is also the option of creating diagrams at runtime. Click a stock, flow or parameter element. This opens an Inspect window with a diagram symbol. In addition, the Inspect window offers the possibility to change parameters at runtime.



Inspect Window

Edit the *Execution mode* to *Real time with scale 1*.

Run the model. Wait a couple of seconds (Model time: years).

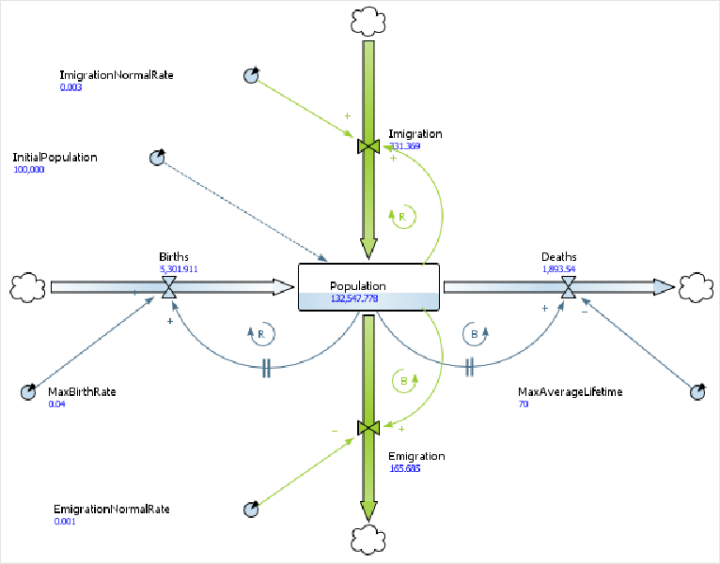
Click the Flow *Births* and open the diagram. Wait a couple of seconds (Model time: years).

Pause the simulation.

Click the Parameter *MaxAverageLifetime* and set the value to less than 70.

Continue the simulation. Watch the change.

Configure Flows Imigration and Emigration



At the beginning of the exercise, you created the Flows *Imigration* and *Emigration* and connected them to the Stock *Population*. Now we want to configure these flows so that they influence the result of the simulation. During the configuration, you can orientate yourself to the Flows *Births* and *Deaths*.

Edit the Color of the flows to *yellowGreen*.

Create the Parameters *ImigrationNormalRate* and *EmigrationNormalRate*.

Edit the Default value of *ImigrationNormalRate* to `0.0025`.

Edit the Default value of *EmigrationNormalRate* to `0.00125`.

Create a positive link between the Parameter *ImigrationNormalRate* and the Flow *Imigration*.

Create a negative link between the Parameter *EmigrationNormalRate* and the Flow *Emigration*.

Create a positive link between the Stock Population and the Flow *Imigration*.

Create a positive link between the Stock Population and the Flow *Emigration*.

Edit the Flow *Imigration*. Imigration = *Population * ImigrationNormalRate.*

Edit the Flow *Emigration*. Imigration = *Population * EmigrationNormalRate*.
Create the two Loop elements.

Run the model.