Process Simulation in manufacturing Tutorials step-by-step with a case study
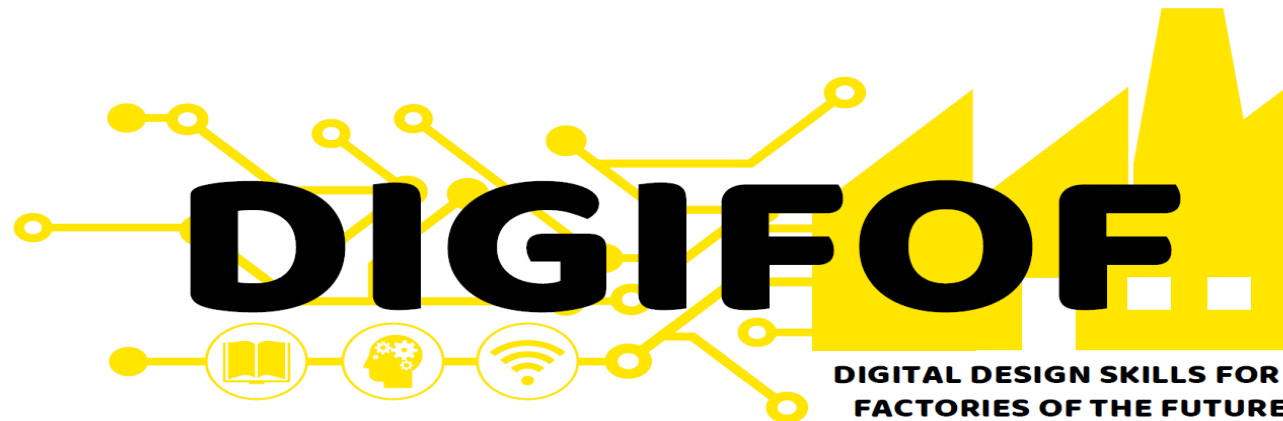
Prof. Fabiana Pirola

DIGIFOF

DIGITAL DESIGN SKILLS FOR FACTORIES OF THE FUTURE
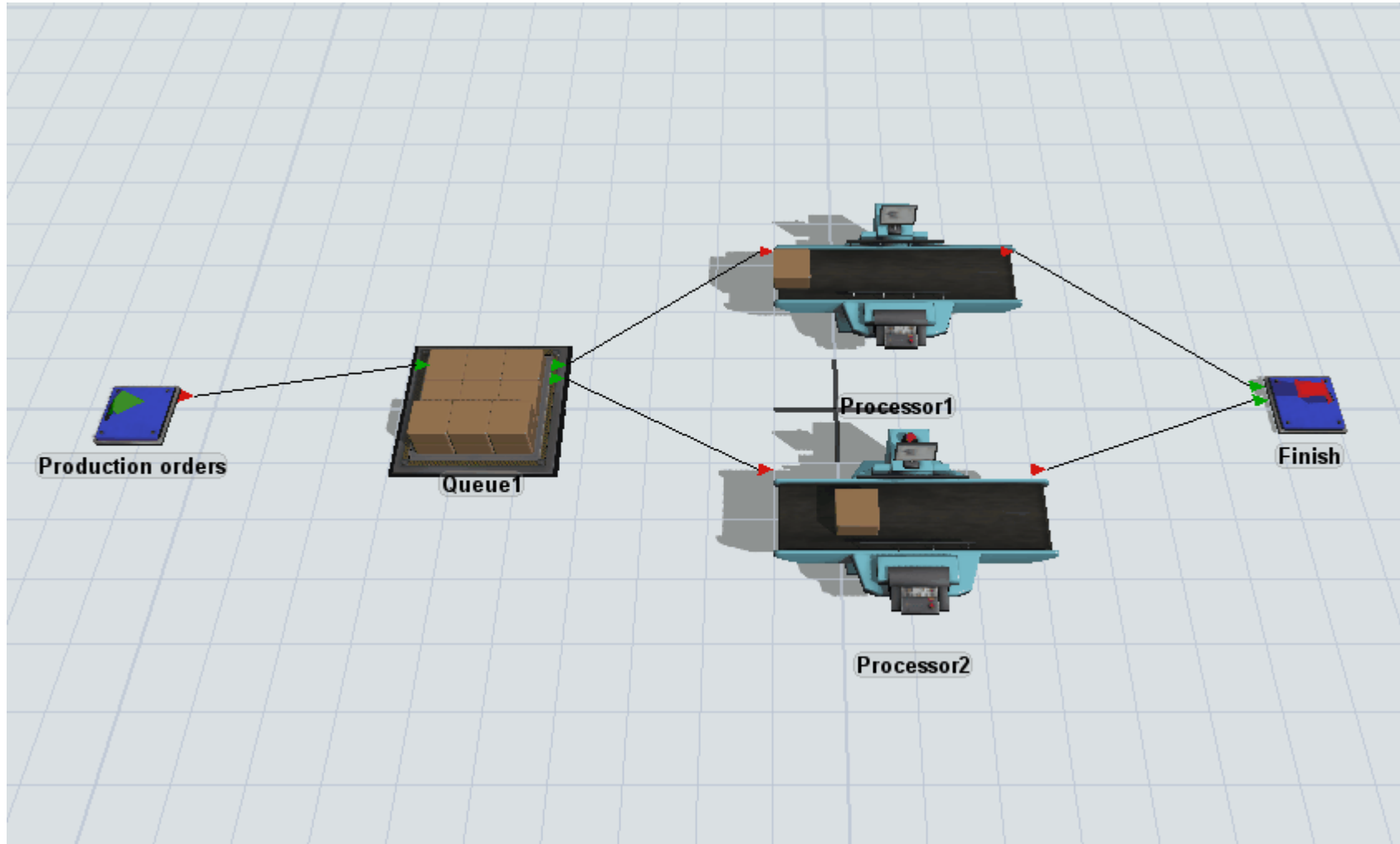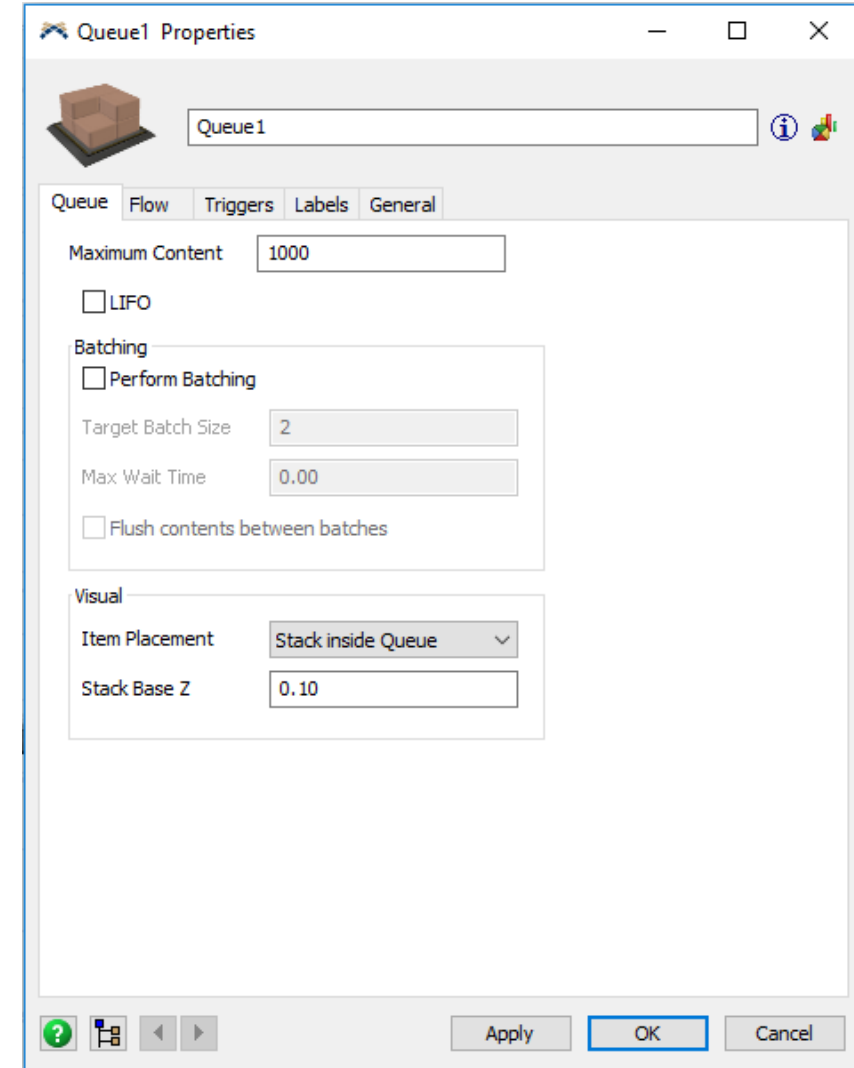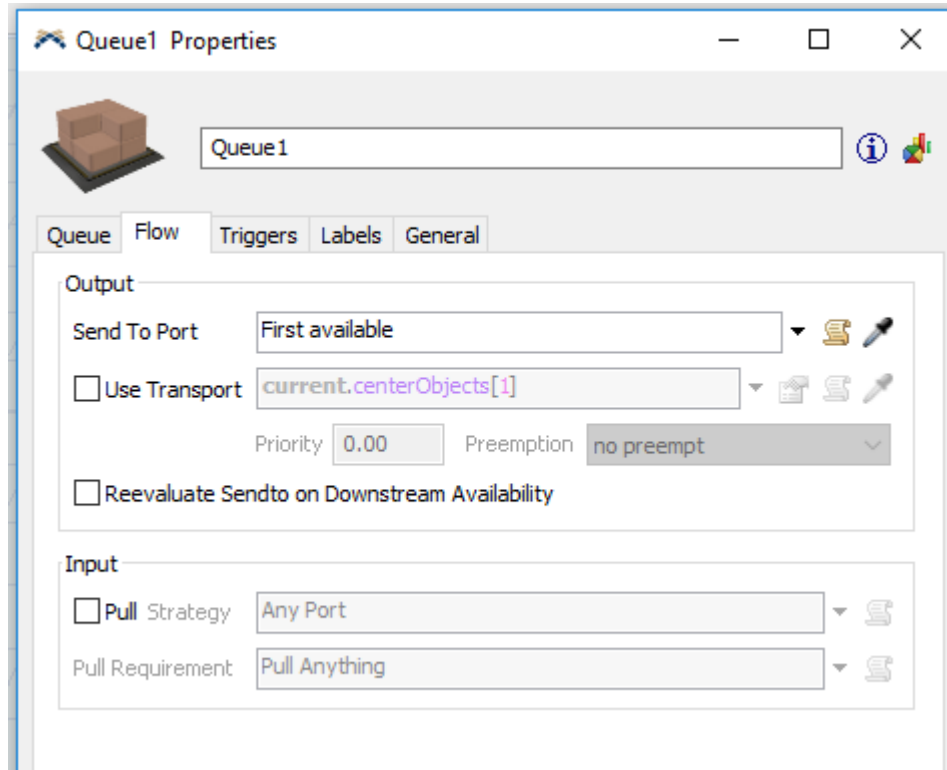
Tutorial 1

Important Concepts:

- Objects´ properties
- Objects´ Statistics
- Objects´interconnections
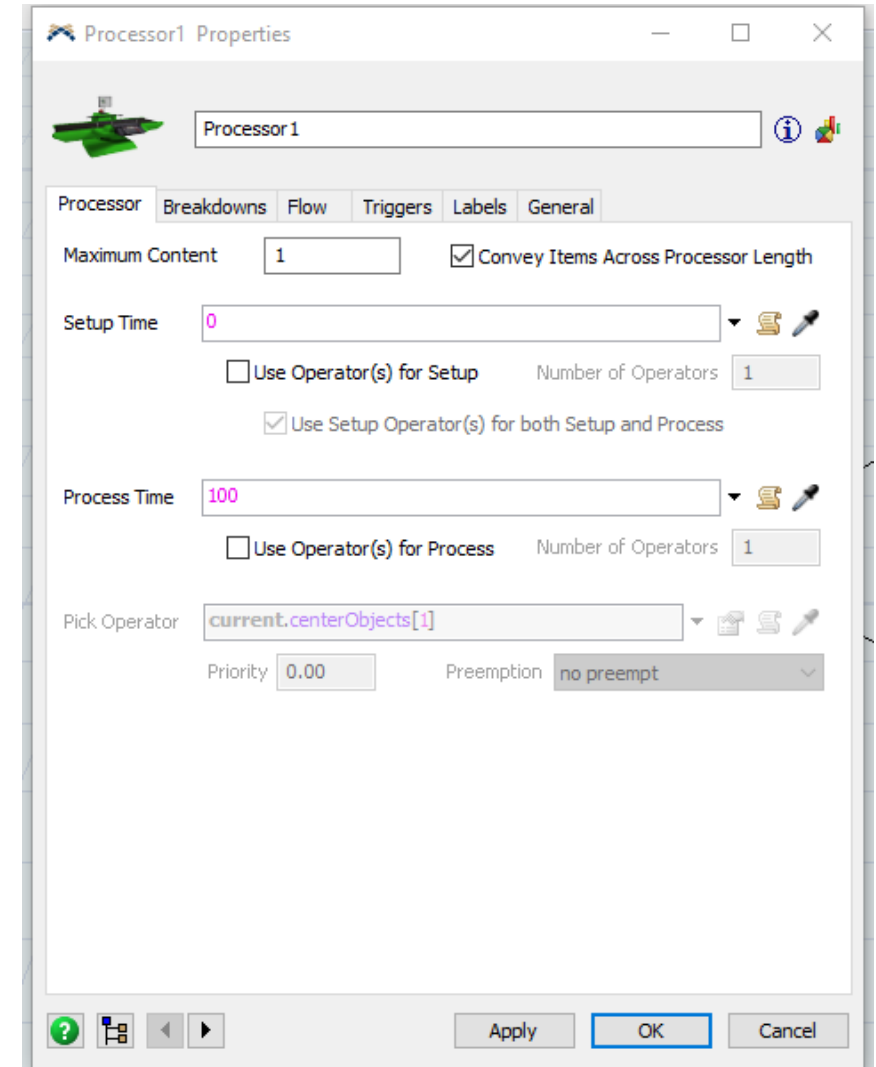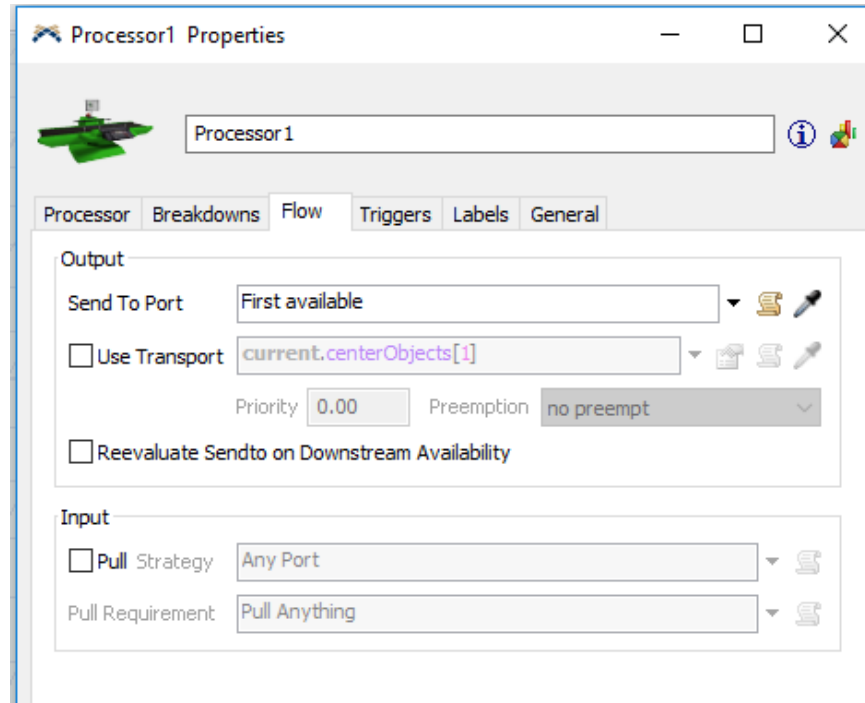- Arrival Style (i.e. Interarrival time)
- Processing time

Tutorial 1

- Drag and drop the module *Queue*
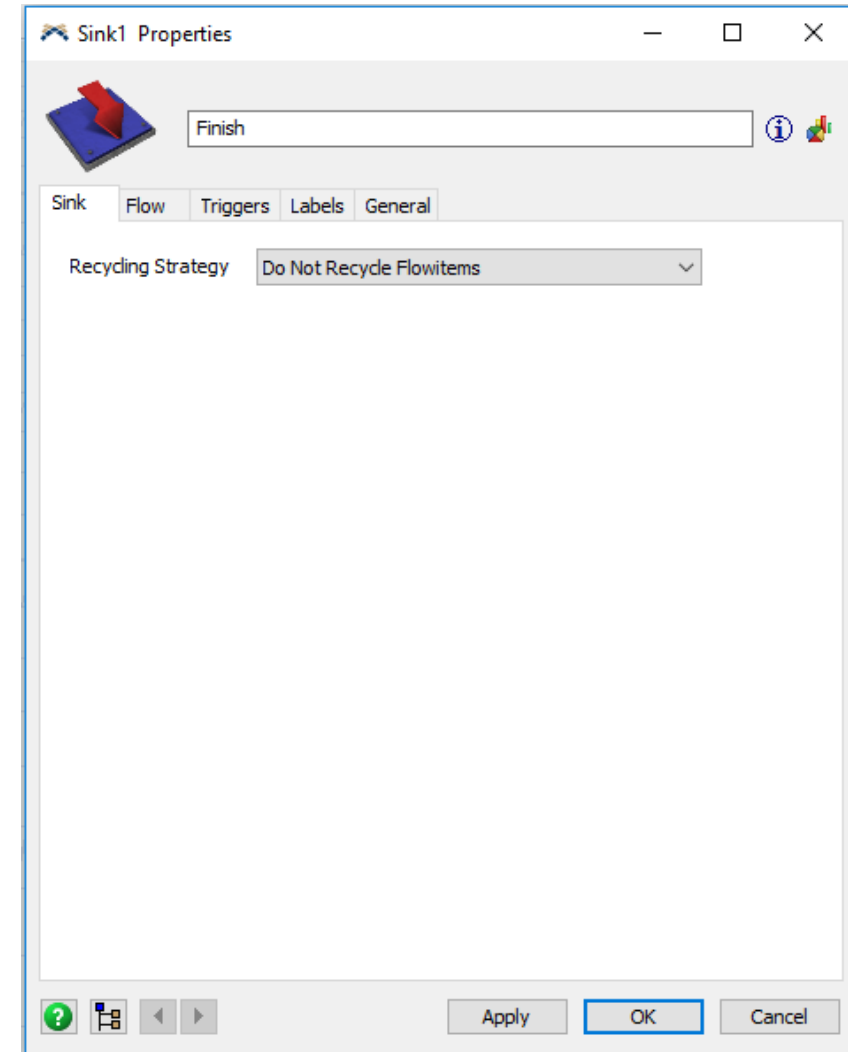- Set the maximum content 1000 and the flow to First available

Tutorial 1

- Drag and drop two modules *Processor*
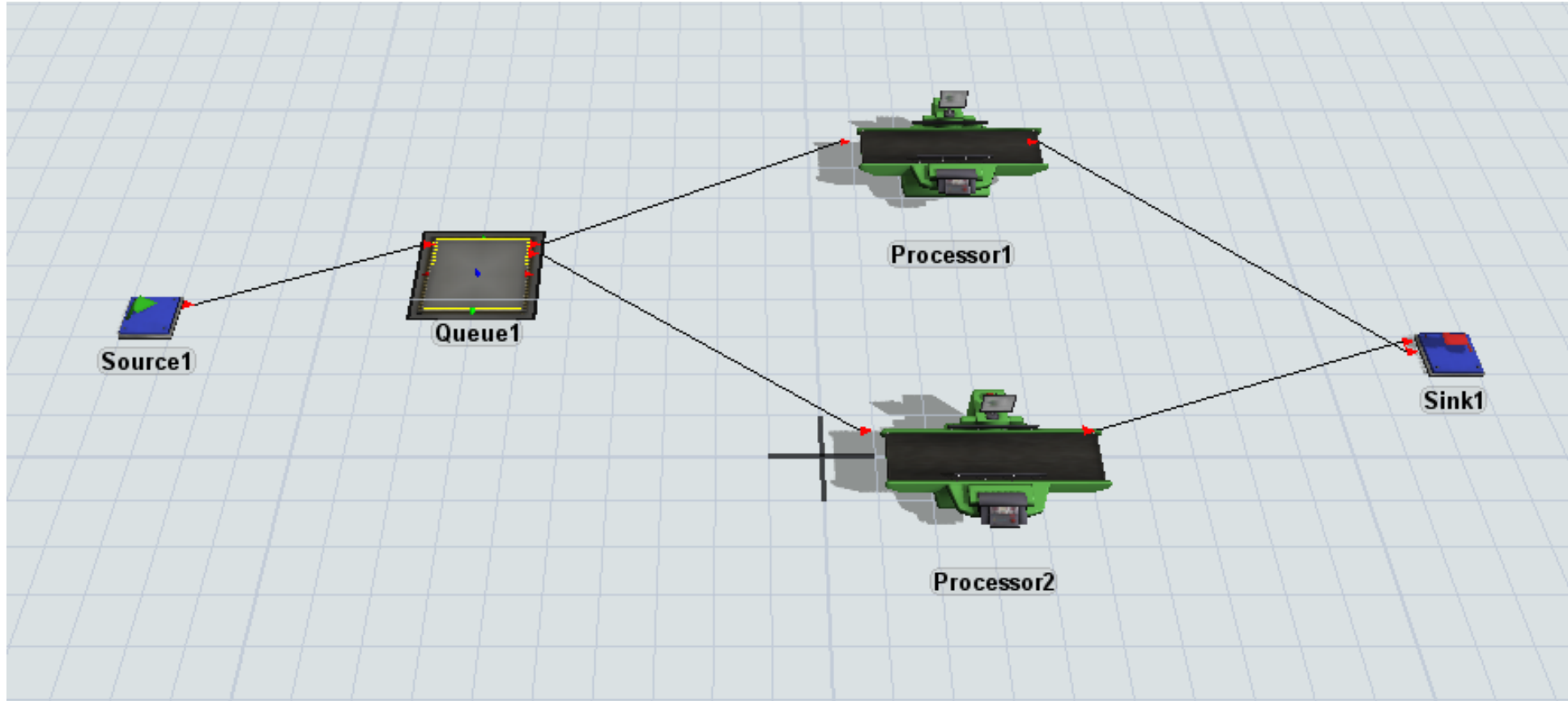- Set the process time = 100 and the flow to First available for both the processors

Tutorial 1

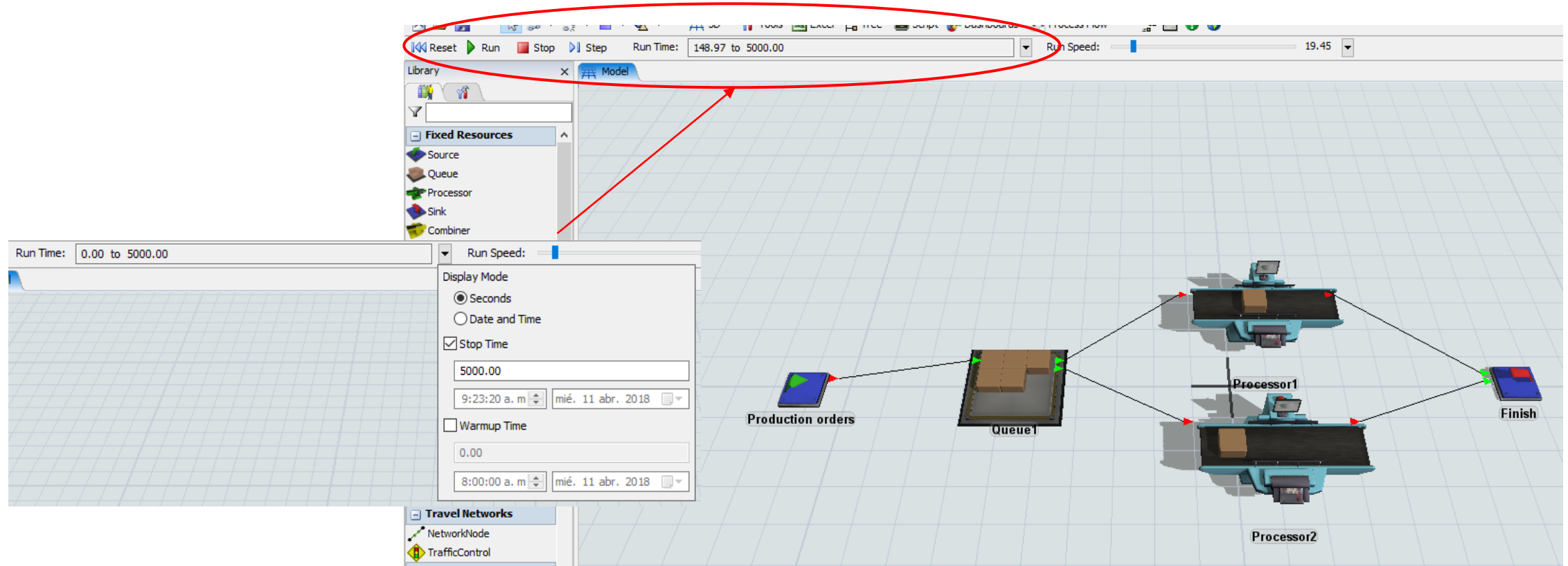- Drag and drop the module *Sink*

- Rename it "Finish"
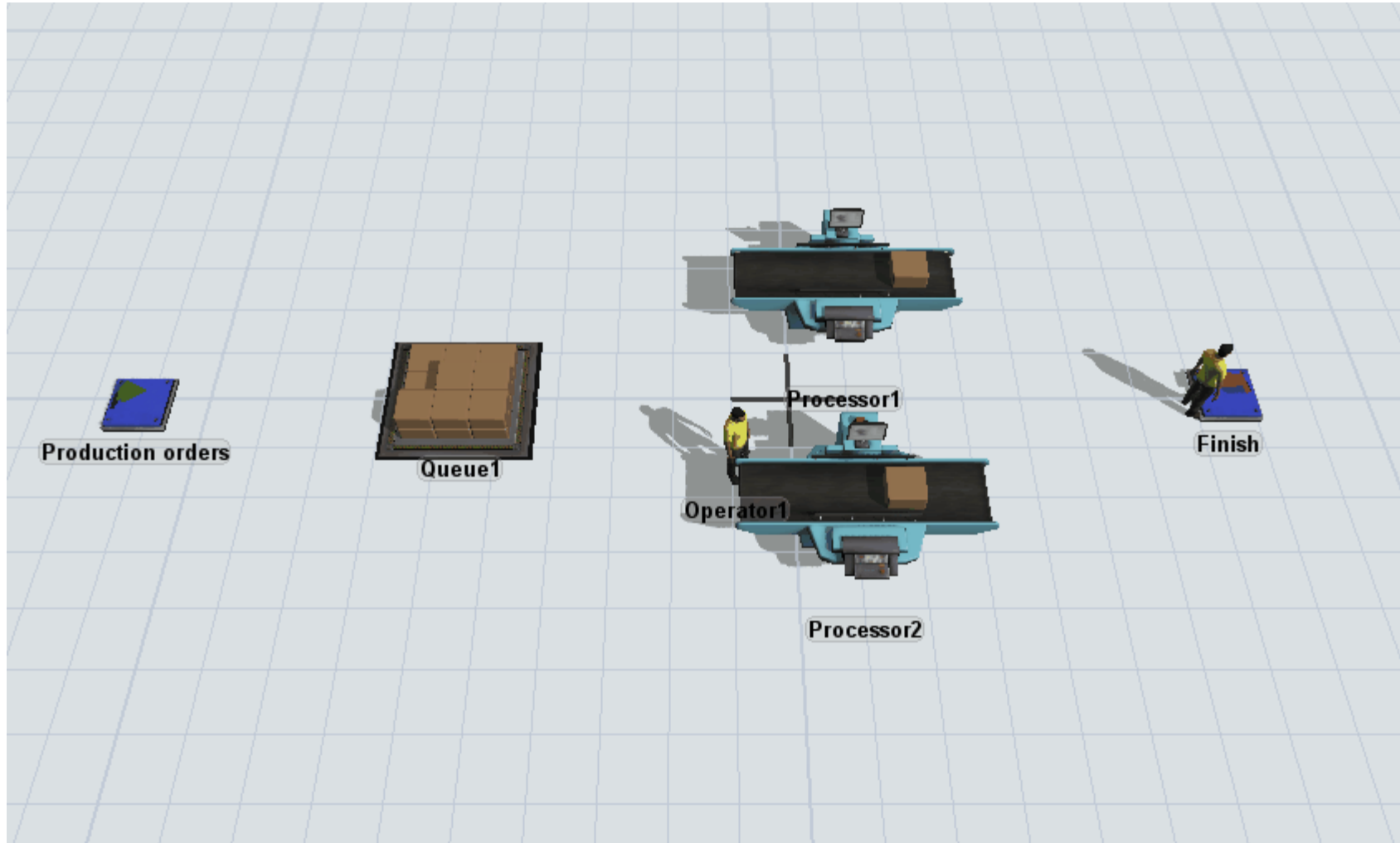
- Connect the objects using the icon ![icon] in the toolbox

- Click on the black arrow at the "Run Time" tab, and define a Stop Time of 5000.
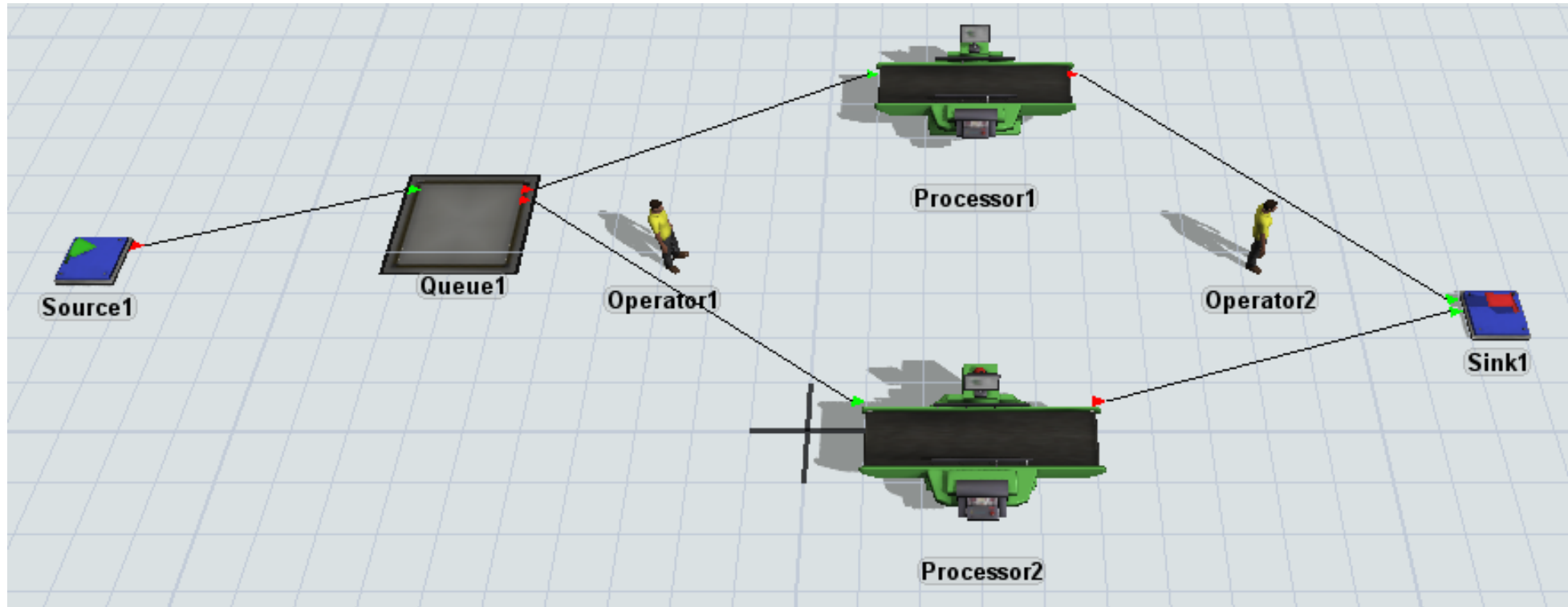- Run the model with the *Run* Button and check for errors.

Tutorial 2

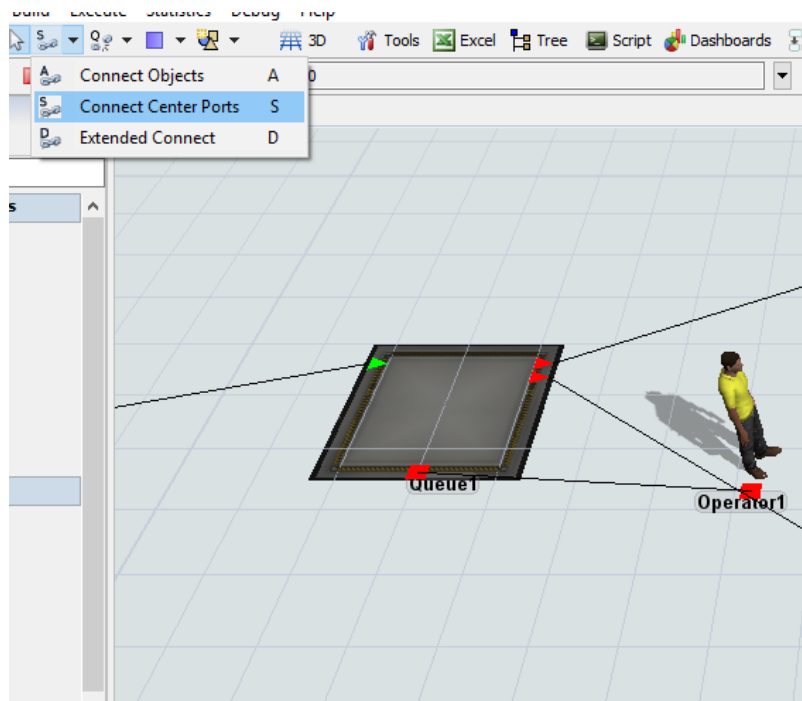## Important Concepts:

- Task executers (transportation)

Tutorial 2

- In the model created from tutorial 1, drag and drop two *Operators*
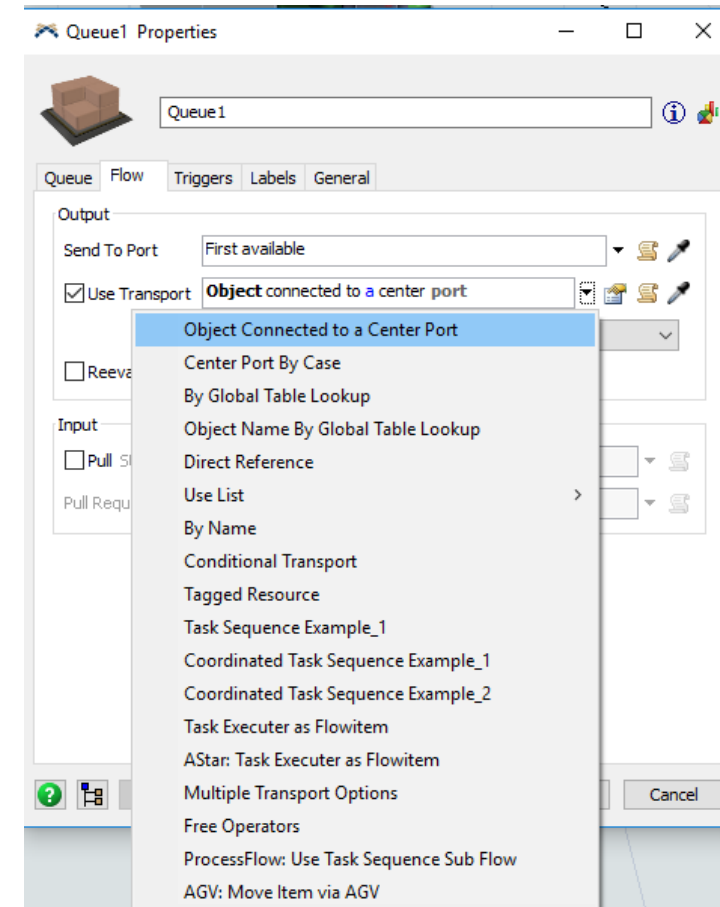
- Set the new properties for the flow from the *Queue* to the *Processors*
   1. Use the option *Connected center ports* to connect the Queue with the Operator 1

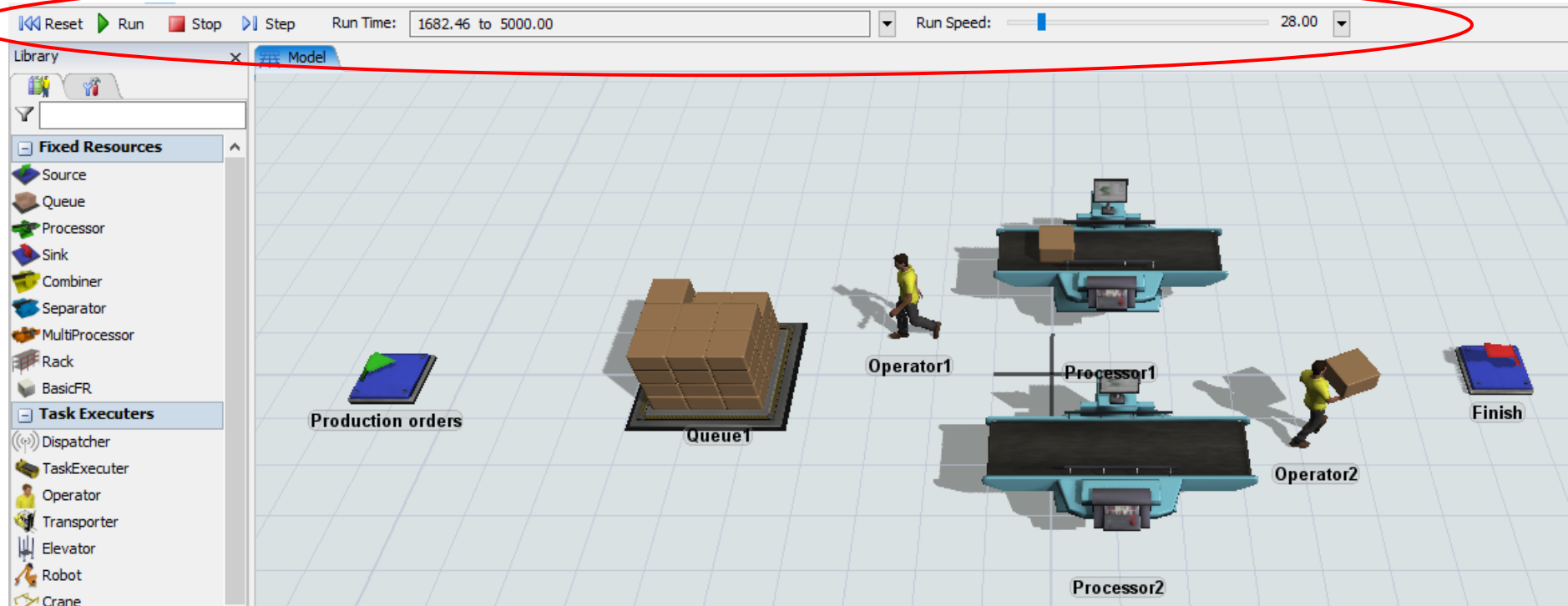2. In the flow settings of the Queue, set the transport Object connected to a center port

Tutorial 2

- ## Set the new properties for the flow from the *Processors* to *Finish* the *Queue*
  - Select Use transport and click the icon
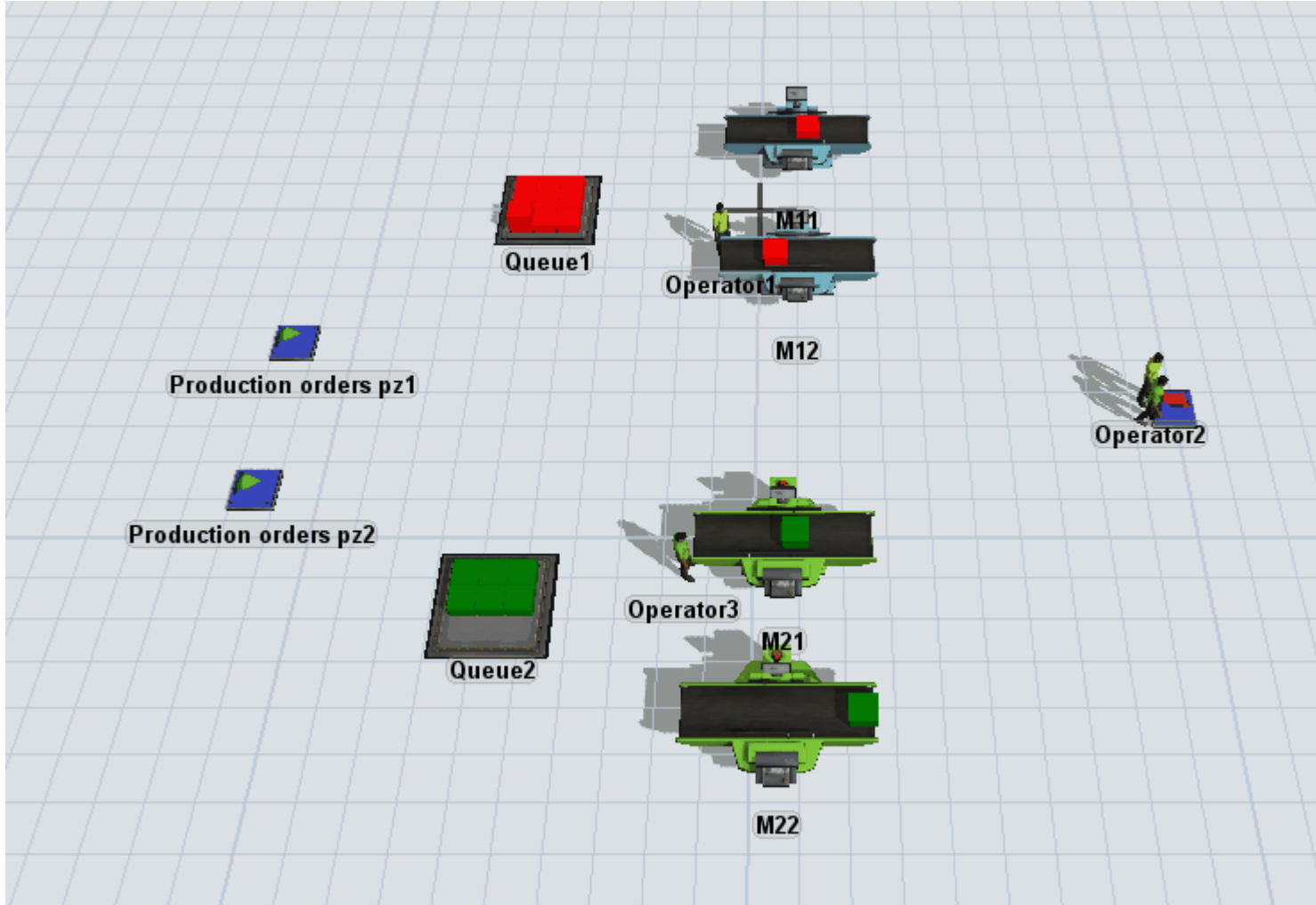 - Now select in the model the "Operator 2" and check the updated settings for the transport
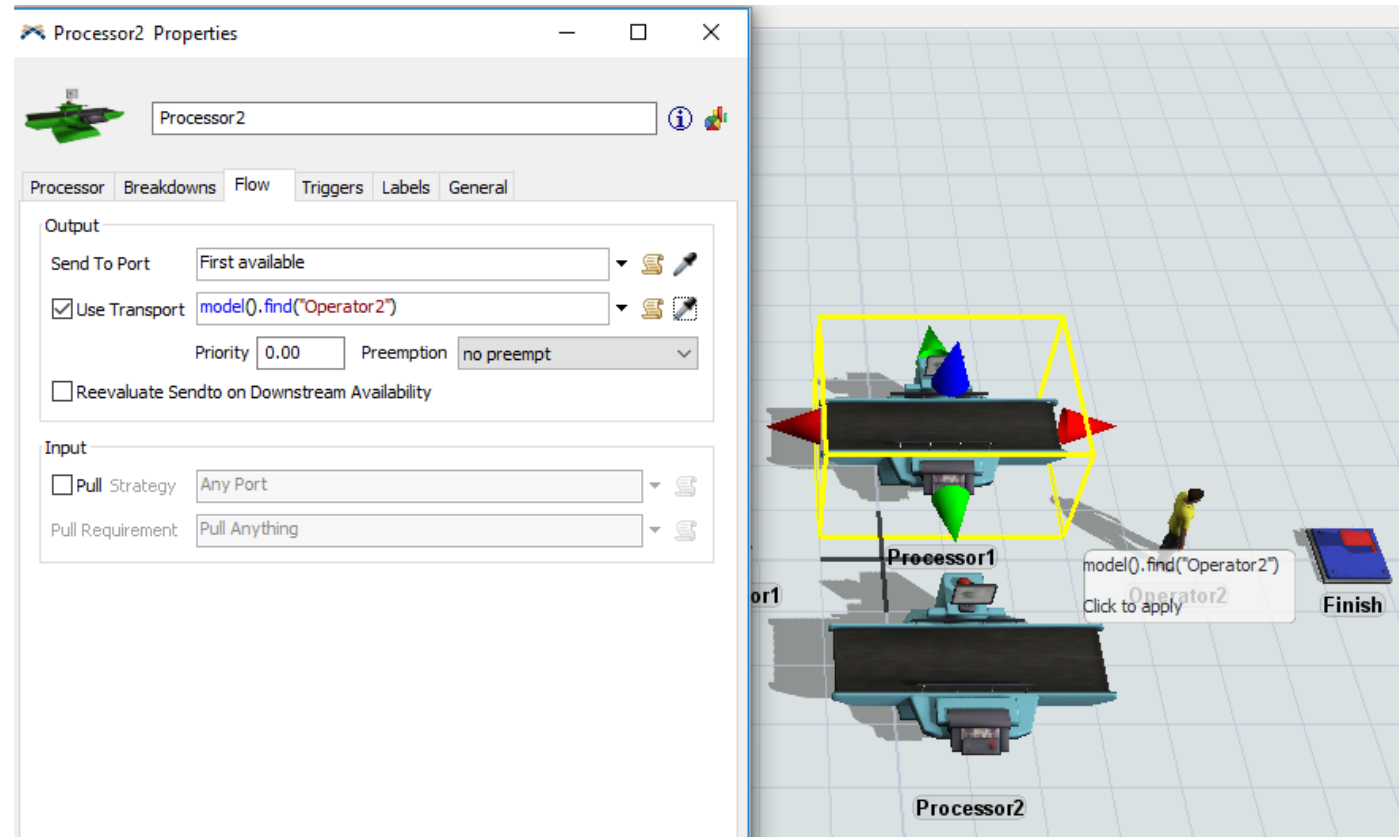
Tutorial 2

- Run the model with the *Run* Button and check for errors
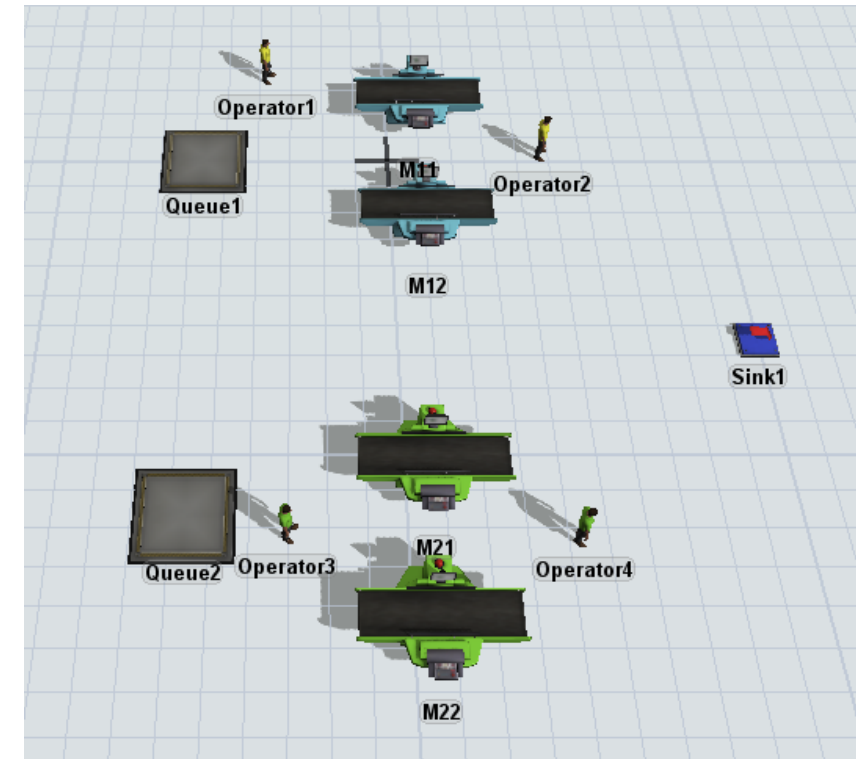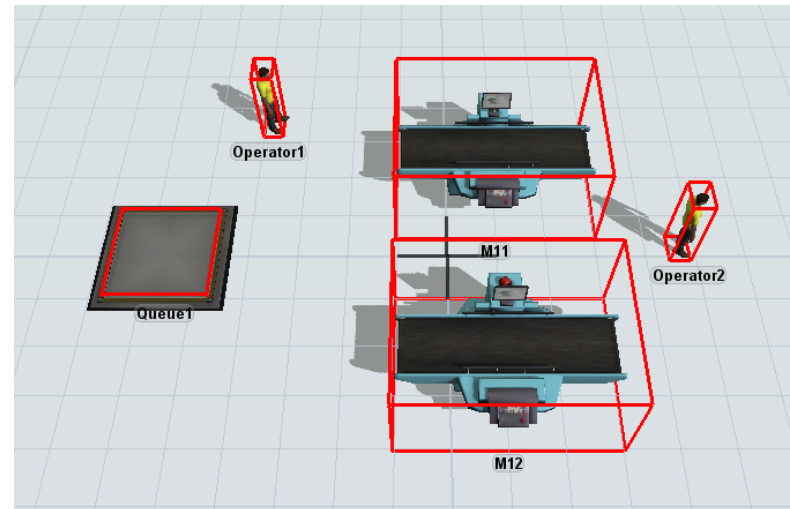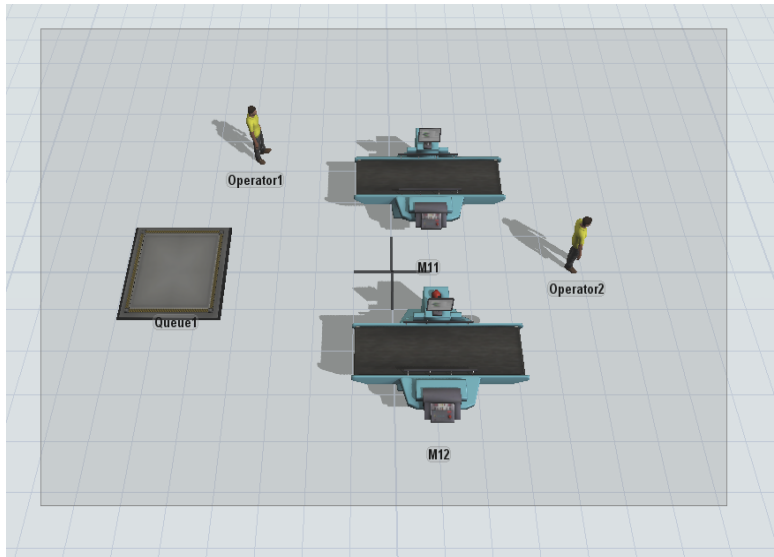
Tutorial 3

Important Concepts:

- Product properties (i.e., type, color)
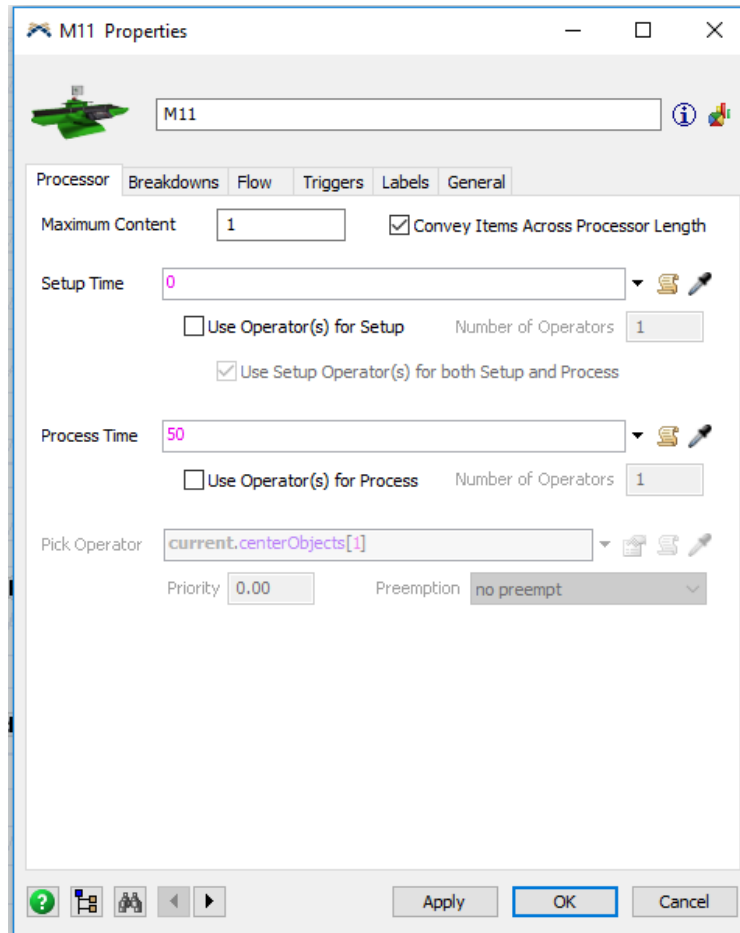- Scalation of production (i.e. Multiple processors´ types)

Tutorial 3

- From the model created in tutorial 2 - select all the elements of the model holding "Shift" and dragging the cursor around them.

- Copy-paste them, Control + C, Control + V

- Rename the objects accordingly.

Tutorial 3

- Change the processing times (i.e M11 = M12, M21 = M22).

Tutorial 3

- Copy-paste the source object of the model and change the names accordingly.
- Define their respective inter-arrival time.

Tutorial 3

- Go to the "Triggers" tab at the source object 1, click on the green plus sign and then "On Creation".
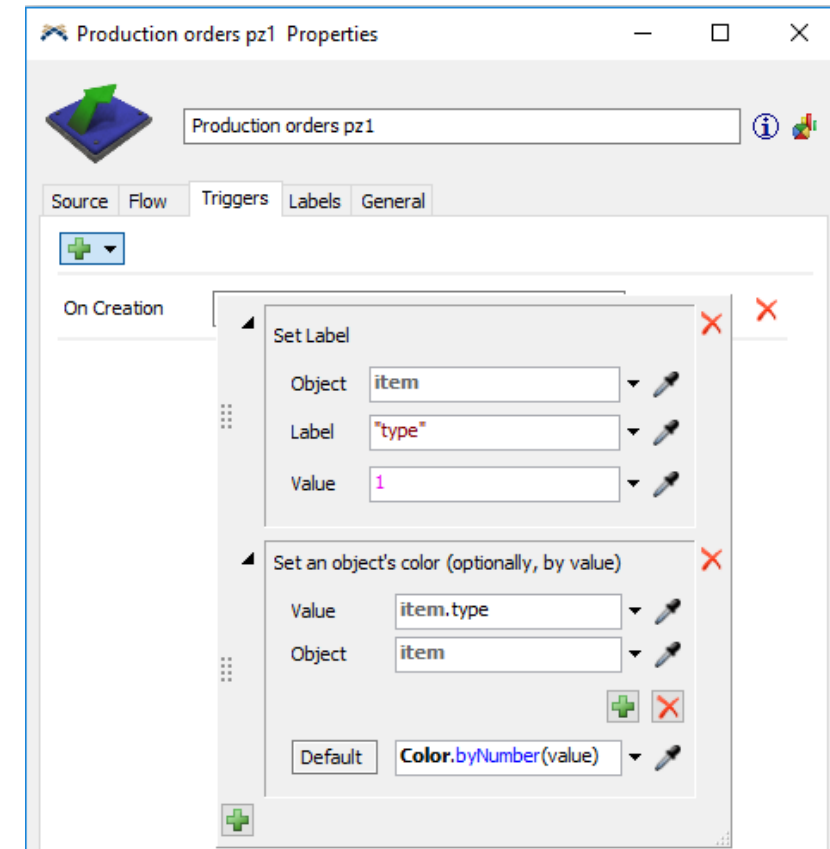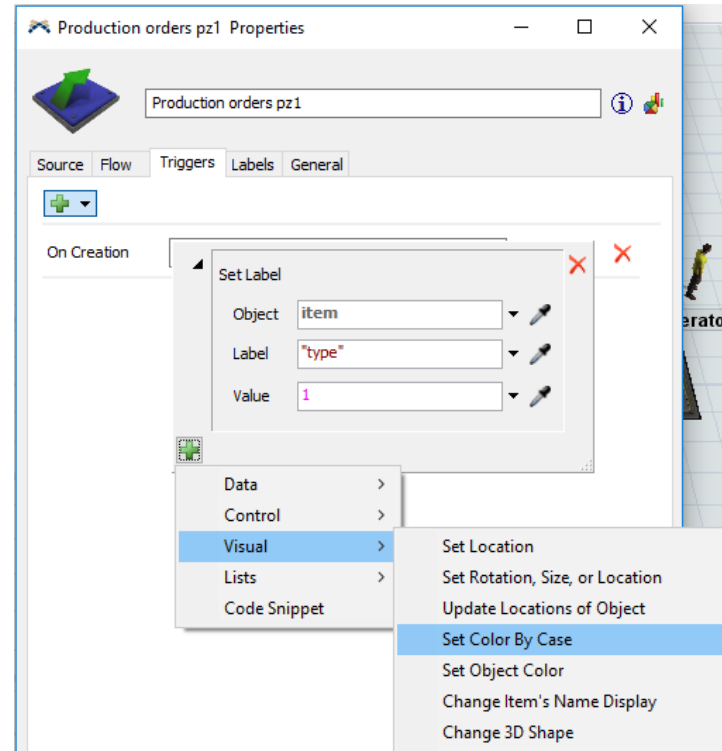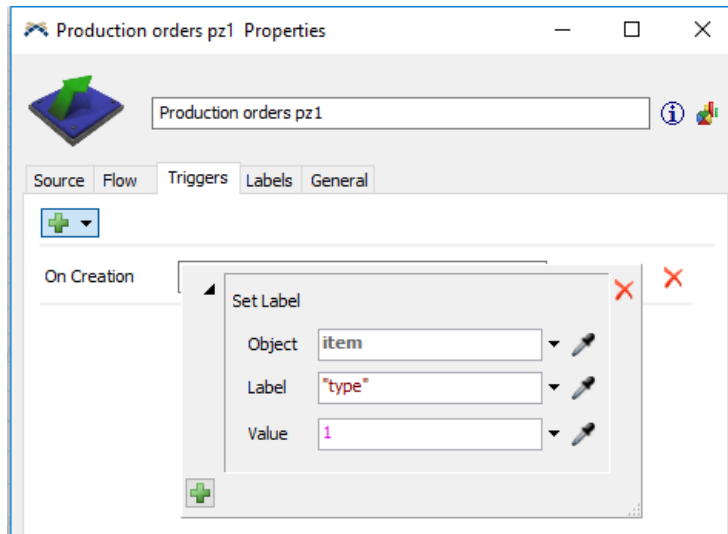
- Then, click on the green plus sign (at the right of "On Creation", then on "Data" and "Set Label".
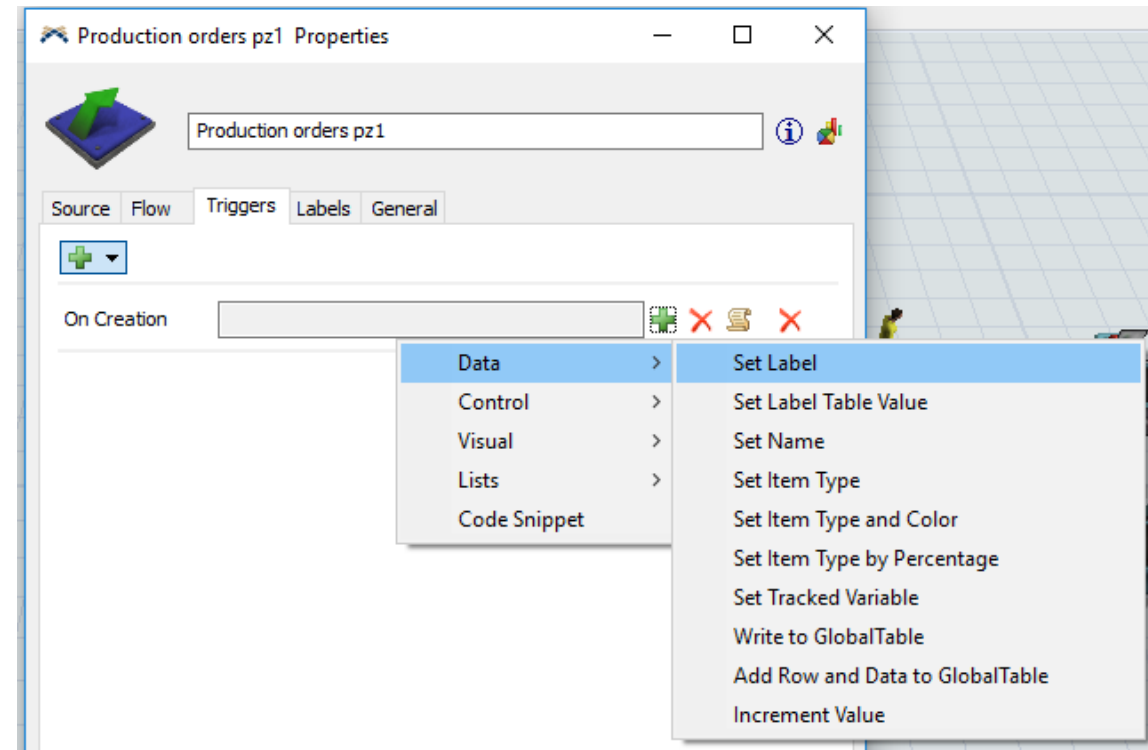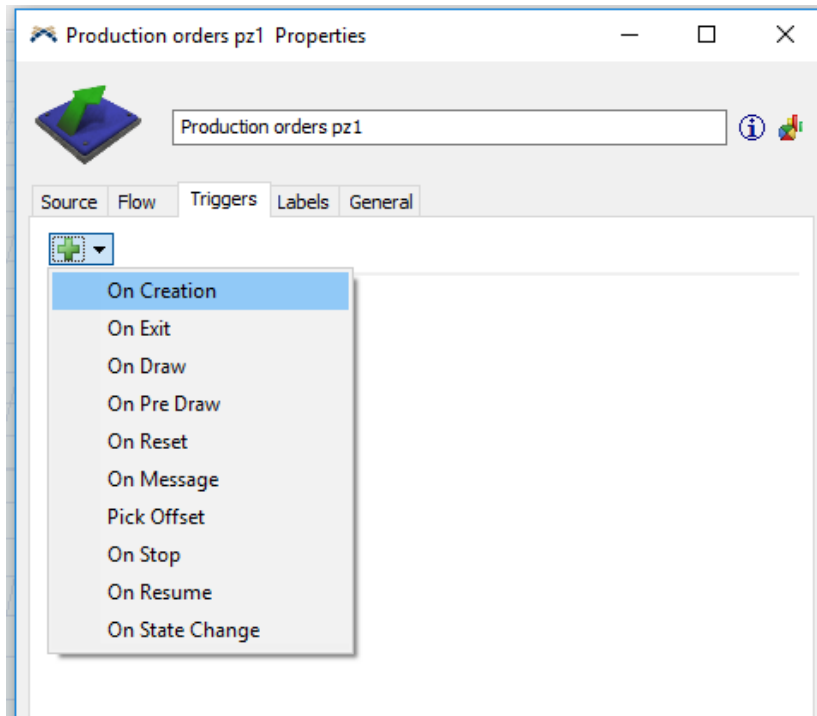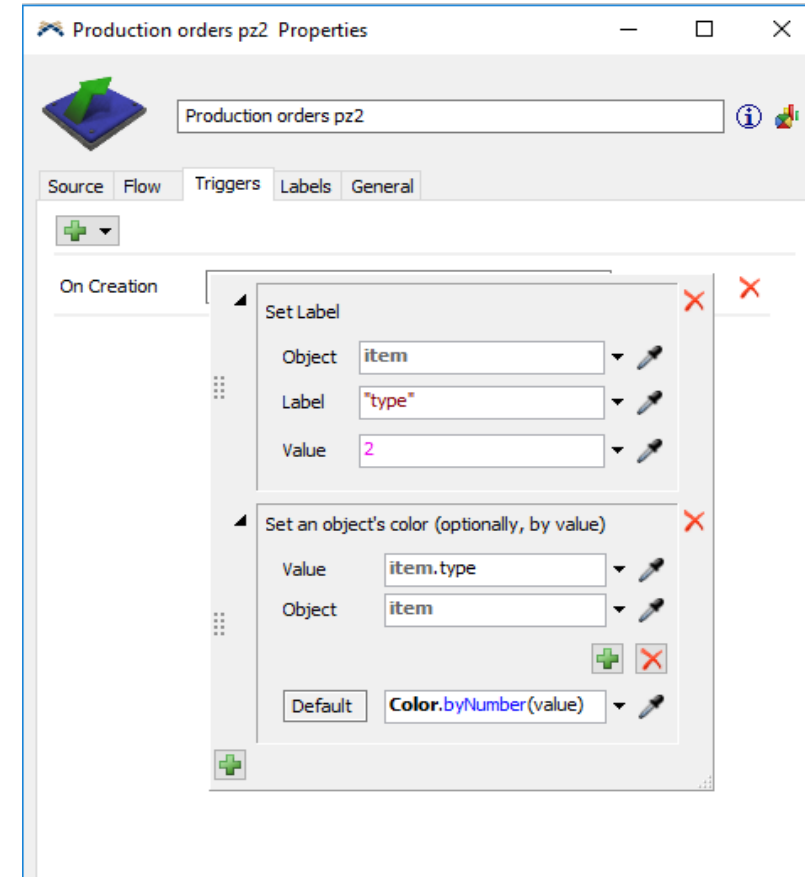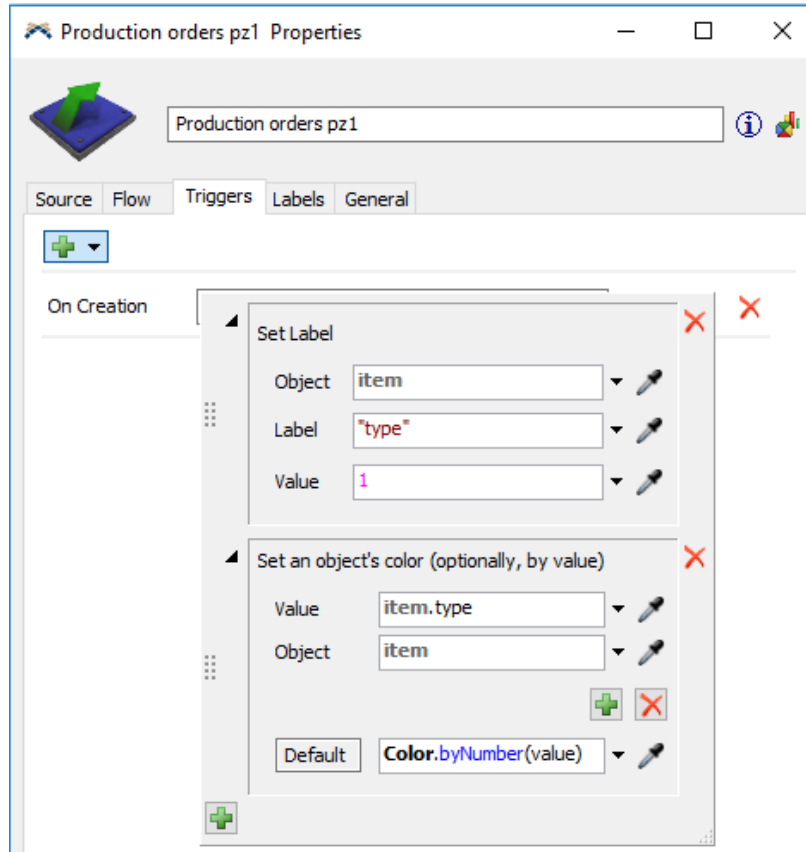
Tutorial 3

- On the Set Label window change the Label to "type" and the value to 1.

- Click on the green plus sign in the bottom left corner of the Set label window, click on "Visual" then "Set Color By Case" and finally change the value to item.type
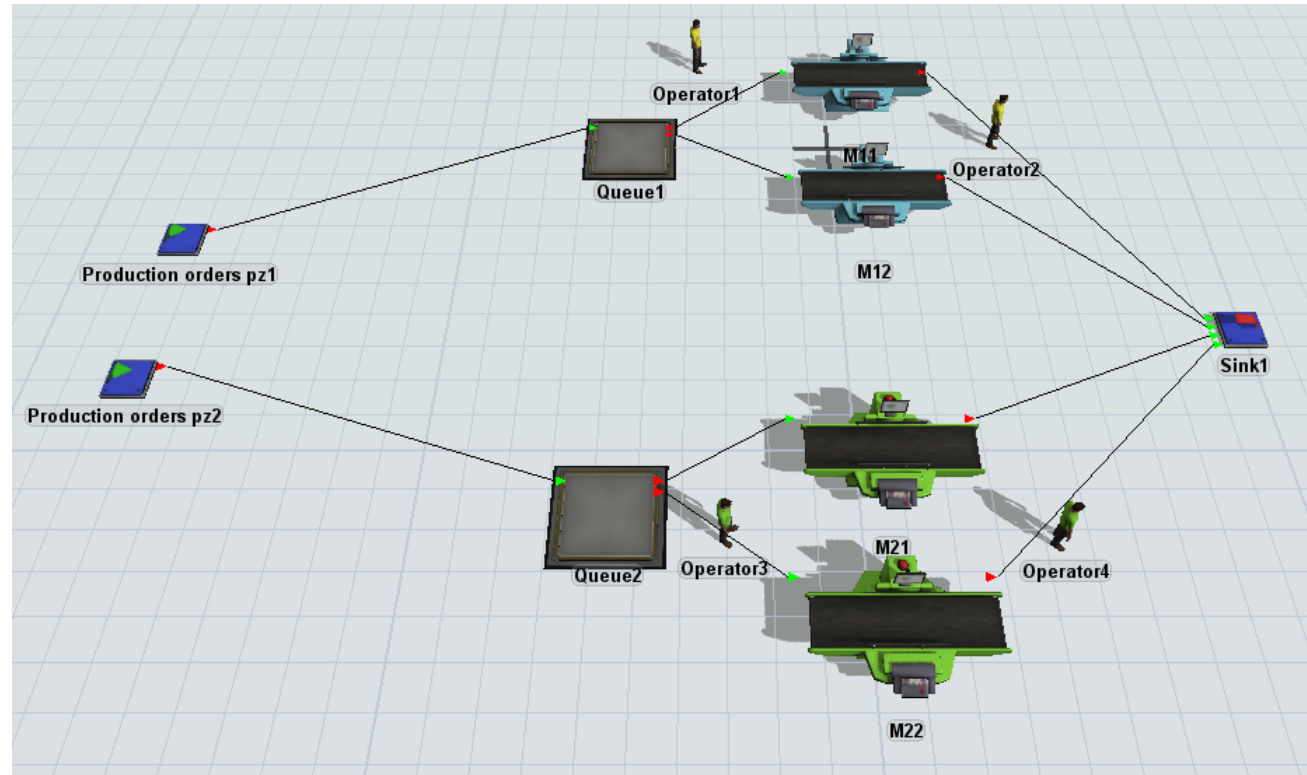
Tutorial 3

- Repeat this process for the other Source object changing the value of the Set Label to 2.
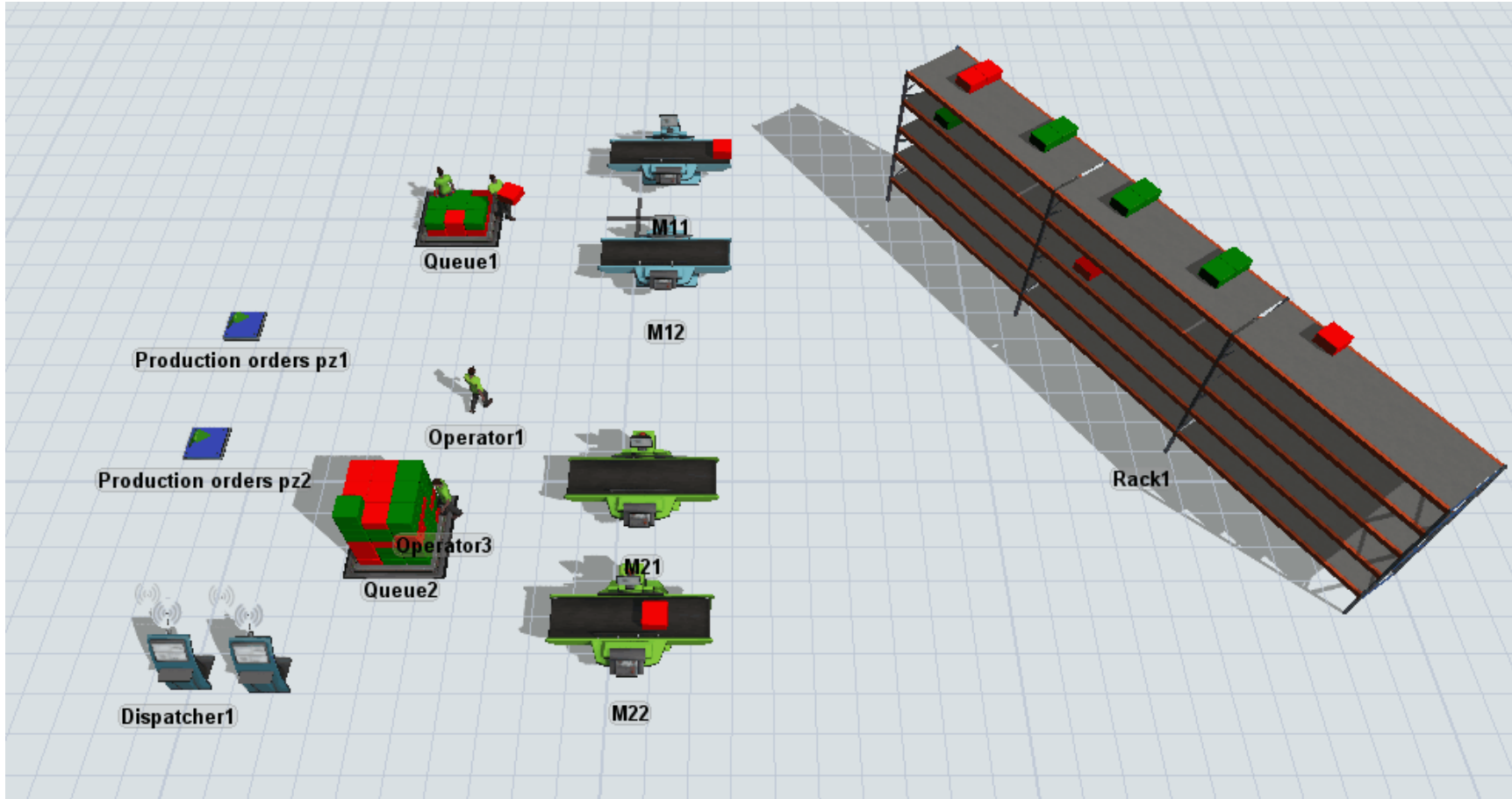
Tutorial 3

- Define the connections among objects.
- Run the model to check for errors.

Tutorial 4

Important Concepts:

- Task executers coordination (i.e. Dispatcher)
- Item List
- Global Tables (i.e., Process time, Process steps)
- Job-shop production sequencing
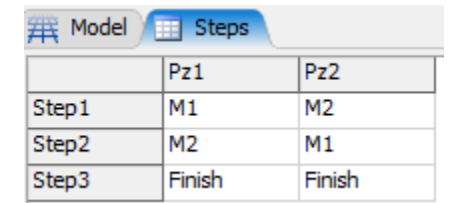- Warehousing (i.e. Rack)

- From the model developed in tutorial 3, we will first eliminate the "Sink" object, and drag and drop a "Rack" fixed resource from the Library and define its properties.
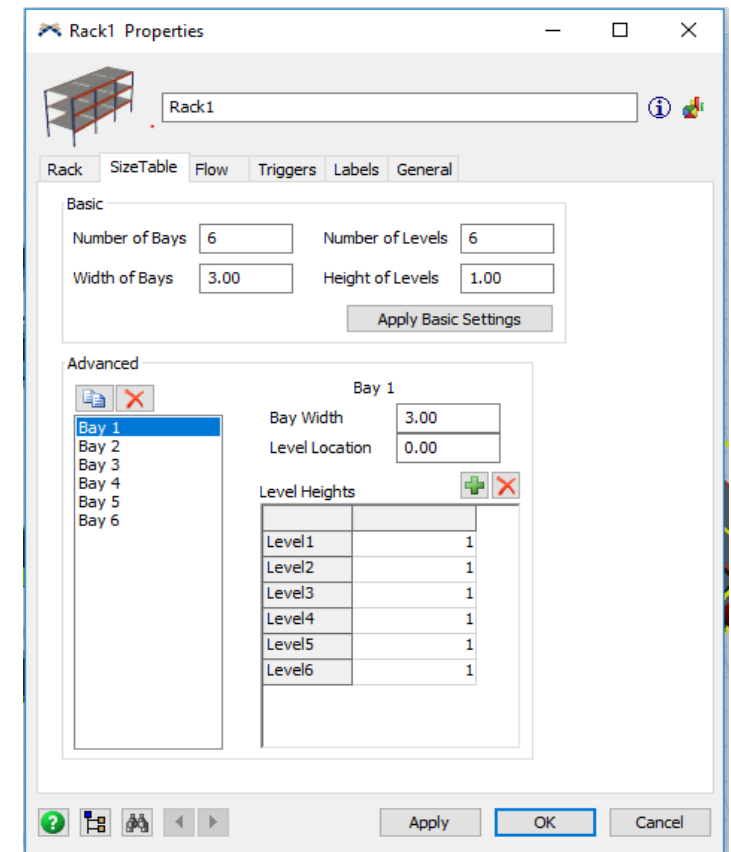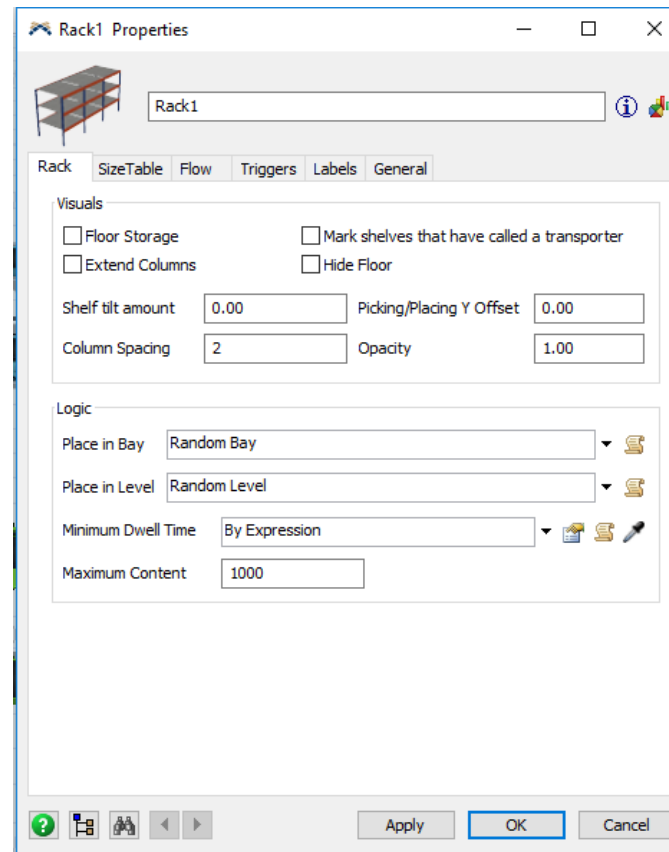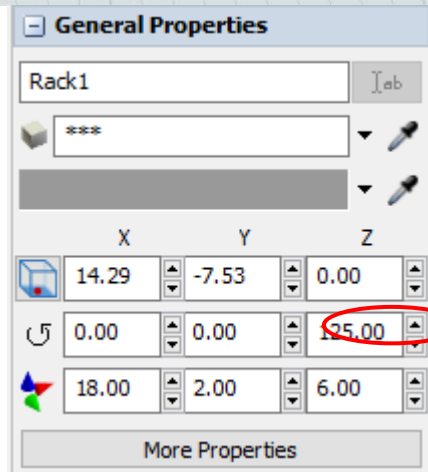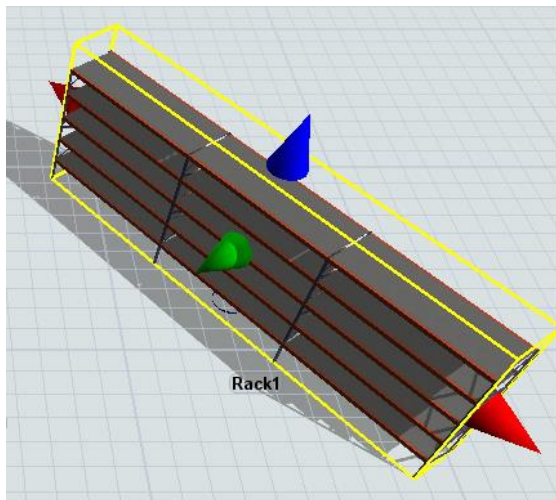
Tutorial 4

- At the Toolbox, click on the green plus sign and then on Global Table.

- In Quick Properties, change the name of the Global Table to "Steps". Modify Rows to 3 and Columns to 2, and then on the table change the names of the column and rows headings.

- Select all the cells of the table, press the secondary click and choose Assign data – Assign String Data, and finally introduce the processing sequence in the table.
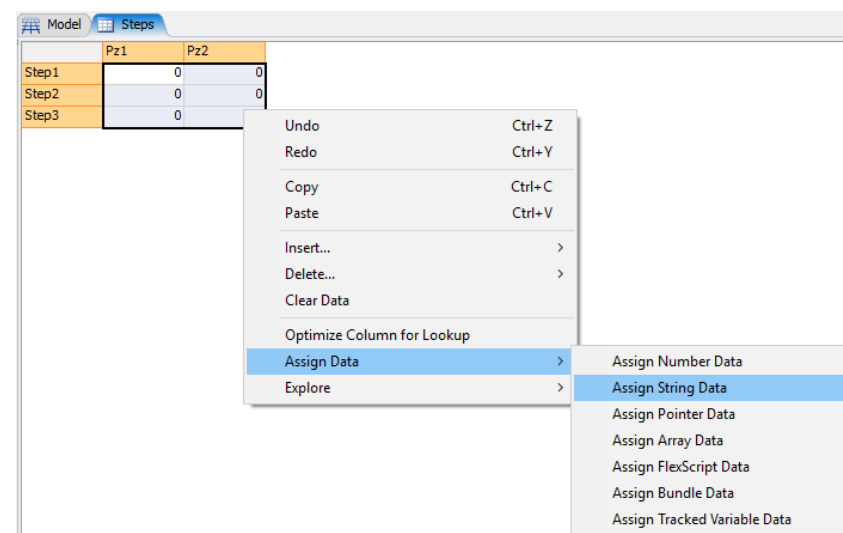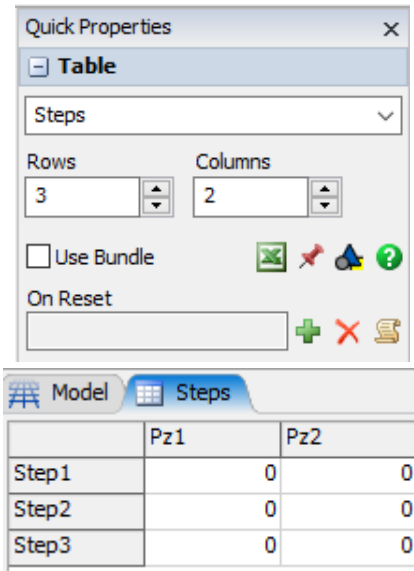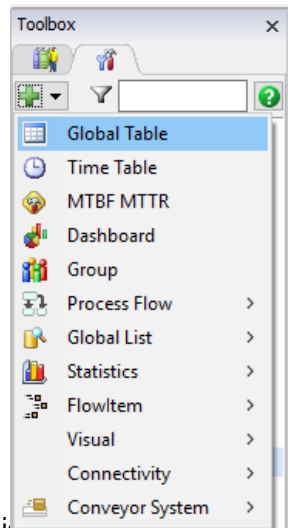
- For all involved fixed resources in the processing sequence, we define at the "Labels" tab the respective operation:
  - Queue1: go to the "Labels" tab, click on the green plus sign, write "operation" in the left cell and "M1" in the right one.
  - Queue2: go to the "Labels" tab, click on the green plus sign, write "operation" in the left cell and "M2" in the right one.
  - Rack1: go to the "Labels" tab, click on the green plus sign, write "operation" in the left cell and "Finish" in the right one.


24
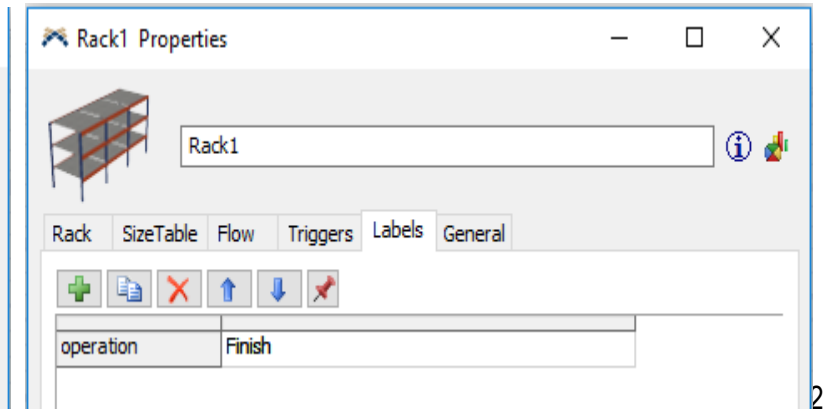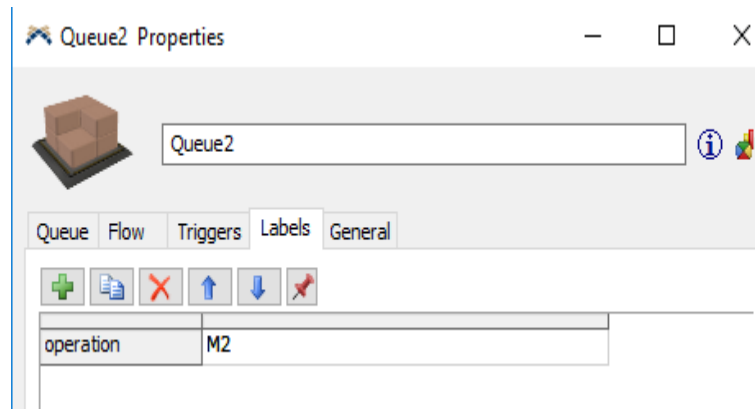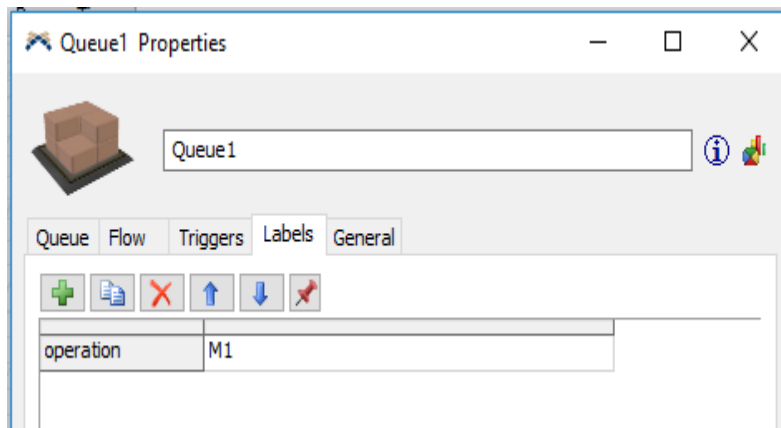
Tutorial 4

- Drag and drop two "Dispatchers" task executers from the Library and name them Dispatcher 1 and Dispatcher 2.

- Using the ☐ type of connection, link the Dispatcher 1 to both operators for machines type 1, and link Dispatcher 2 to both operators for machines type 2.

- In the properties define the Pass to as "Shortest distance if available".
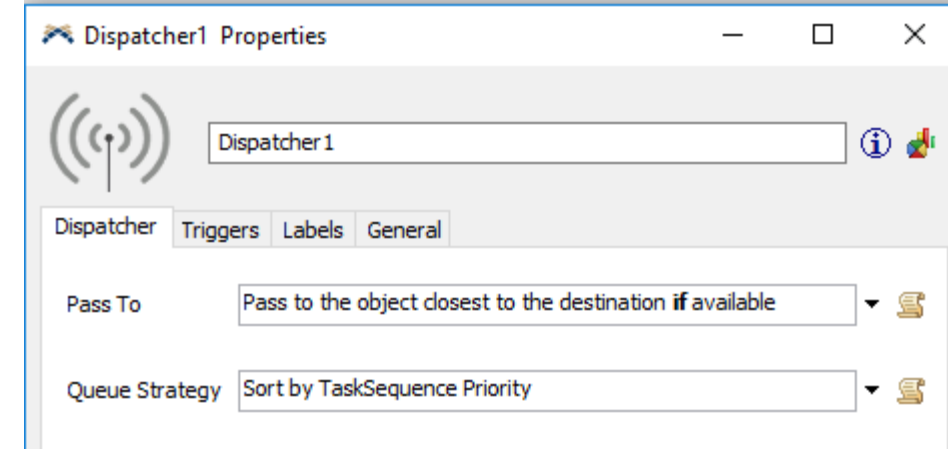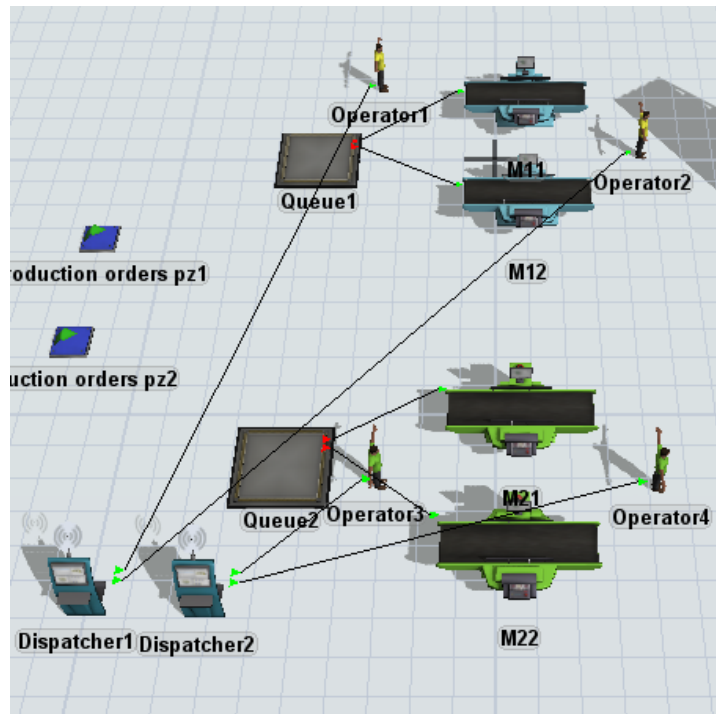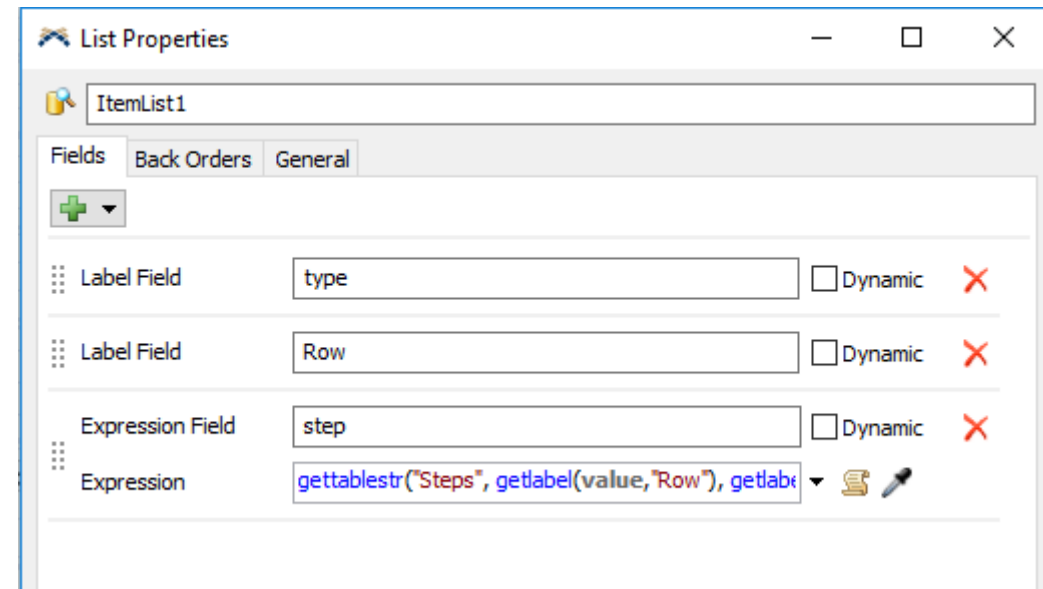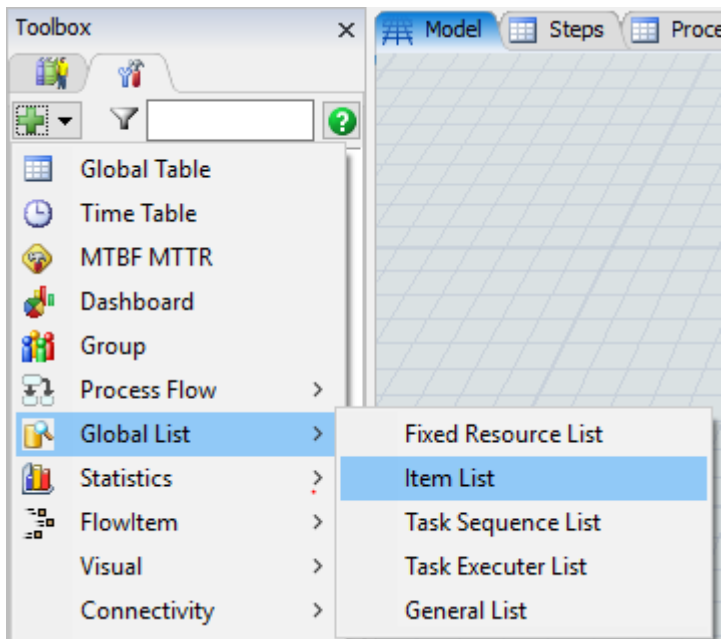
Tutorial 4

- In both Source objects at the "Triggers" tab we incorporate a new label (as explained in tutorial 3) named "Row" with a Value equal to 1.
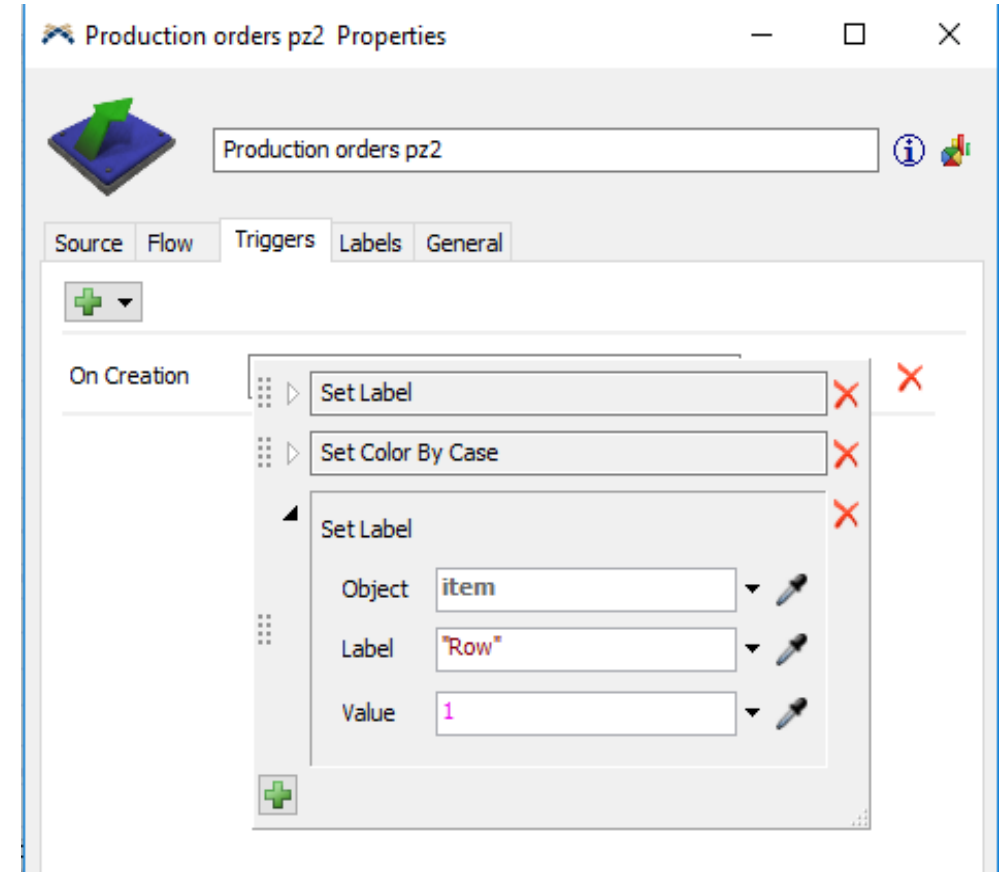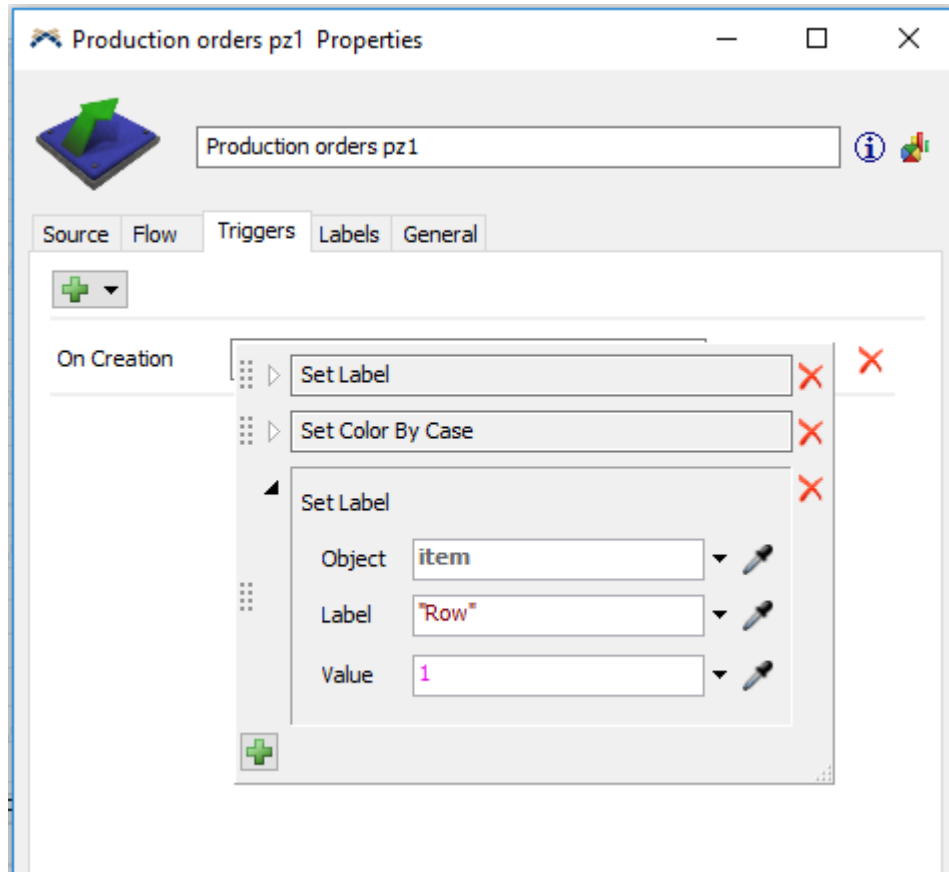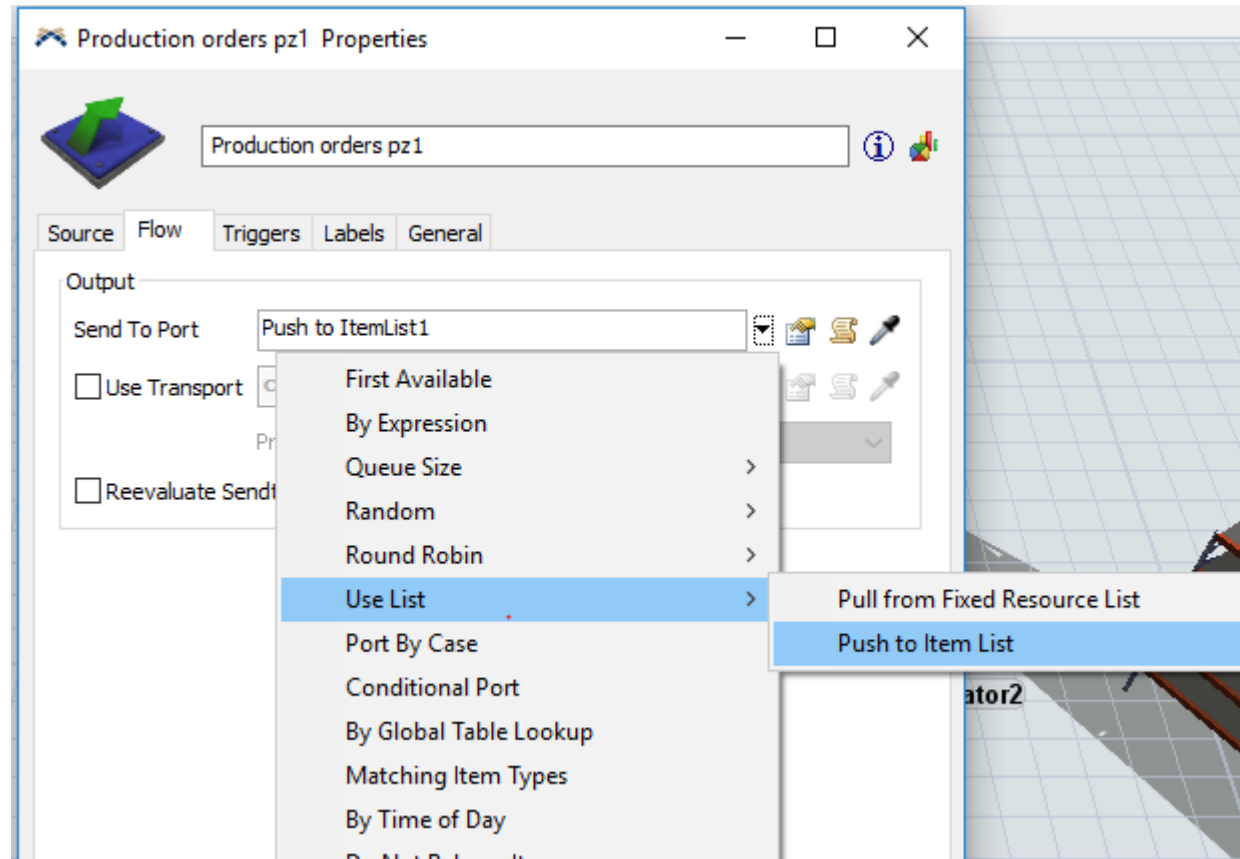
Tutorial 4

- In the Toolbox, select "Global List" and then "Item List".
- In the Item List properties, click on the green plus sign and create 2 Label Fields and 1 Expression Field.
- At the first Label field write "type", and in the second write "Row".
- At the Expression Field write "step" with the following Expression:

gettablestr("Steps", getlabel(**value**,"Row"), getlabel(**value**, "type"))
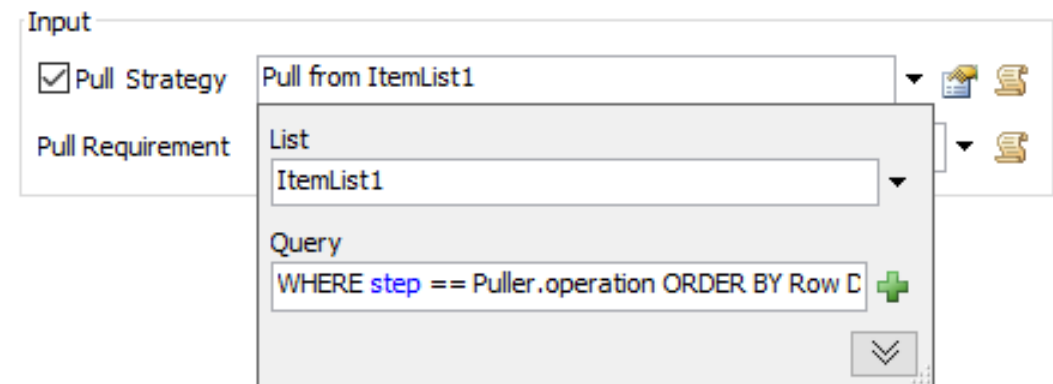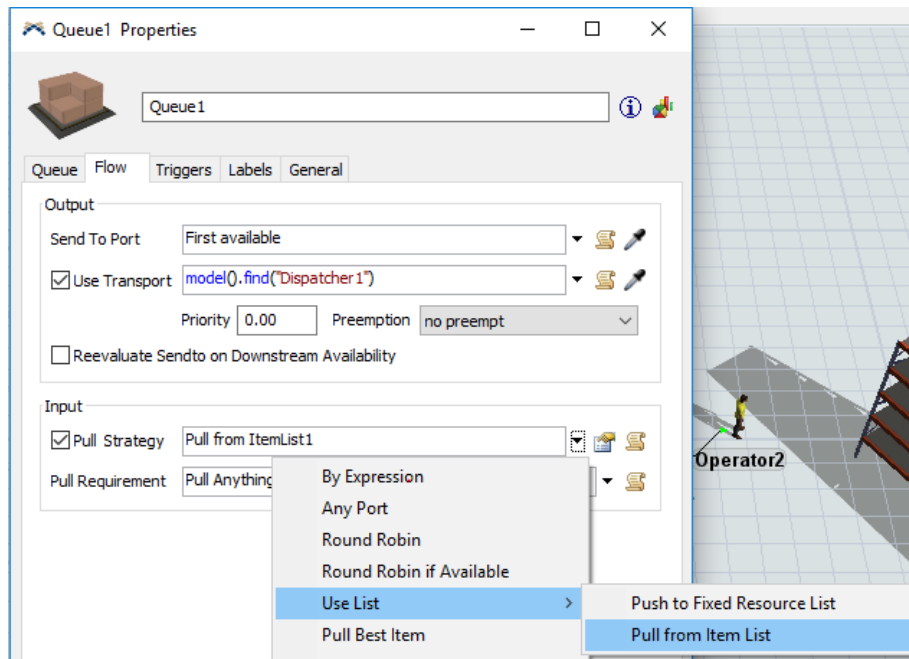
Tutorial 4

- In both Source objects, go to the "Flow" tab and then in the Output window select Send to Port as: Use List – Push to Item List, and select the recently created ItemList1
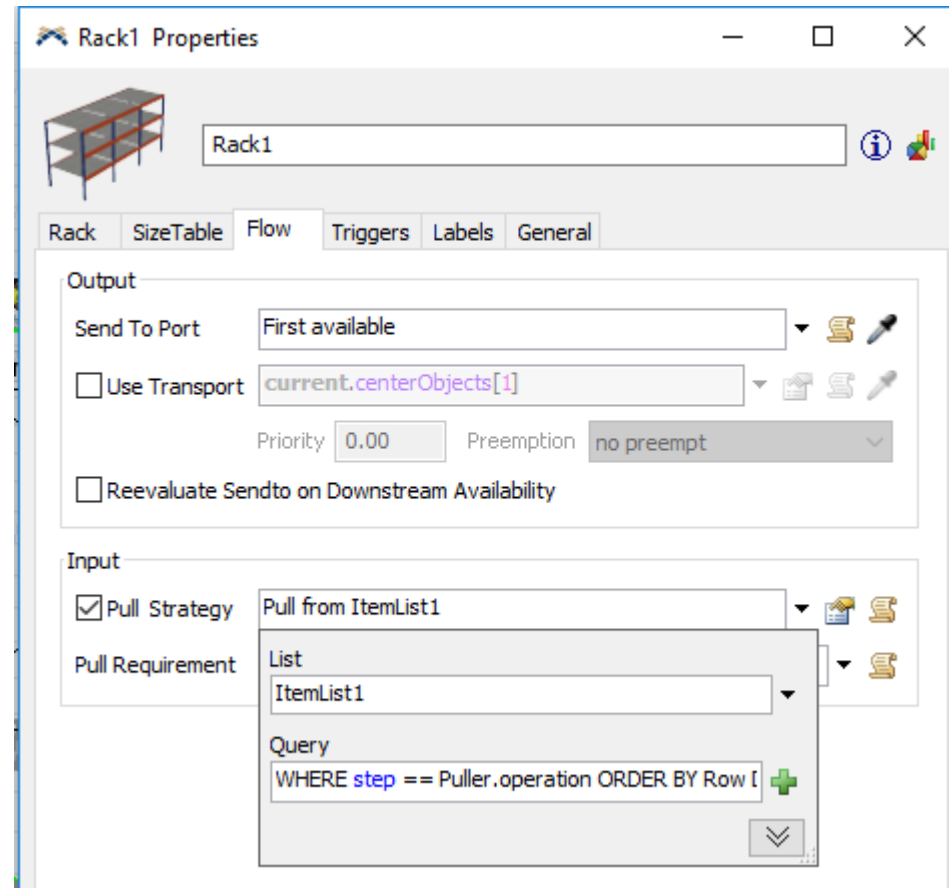
Tutorial 4

- In both Queues in the "Flow" tab, select the Output properties as Sent to Port: First available, click on "Use Transport" and sample   the corresponding Dispatcher from the model.
- For the Input properties, select Use List – Pull from Item List, and select the ItemList1. Define the "Query" as:

WHERE step == Puller.operation ORDER BY Row DESC

Tutorial 4

• Use the same "Query" in the Rack1 Object Pull Strategy.

Tutorial 4

- In all processors, at the "Flow" tab we select as in the Source Objects Output properties to Push to ItemList1 using the corresponding Dispatcher as Transport.
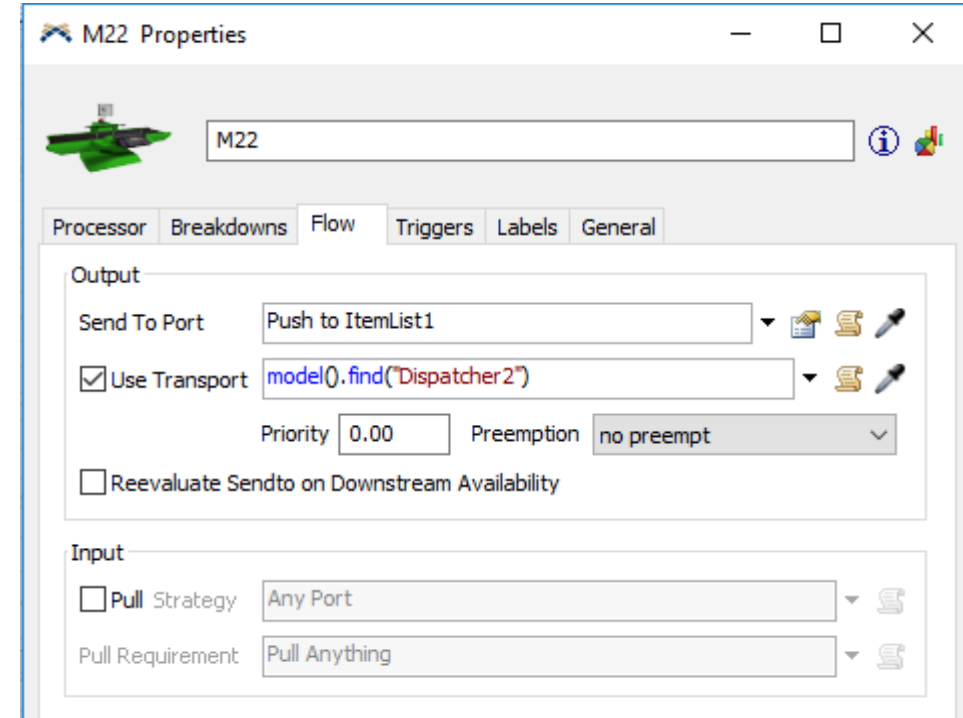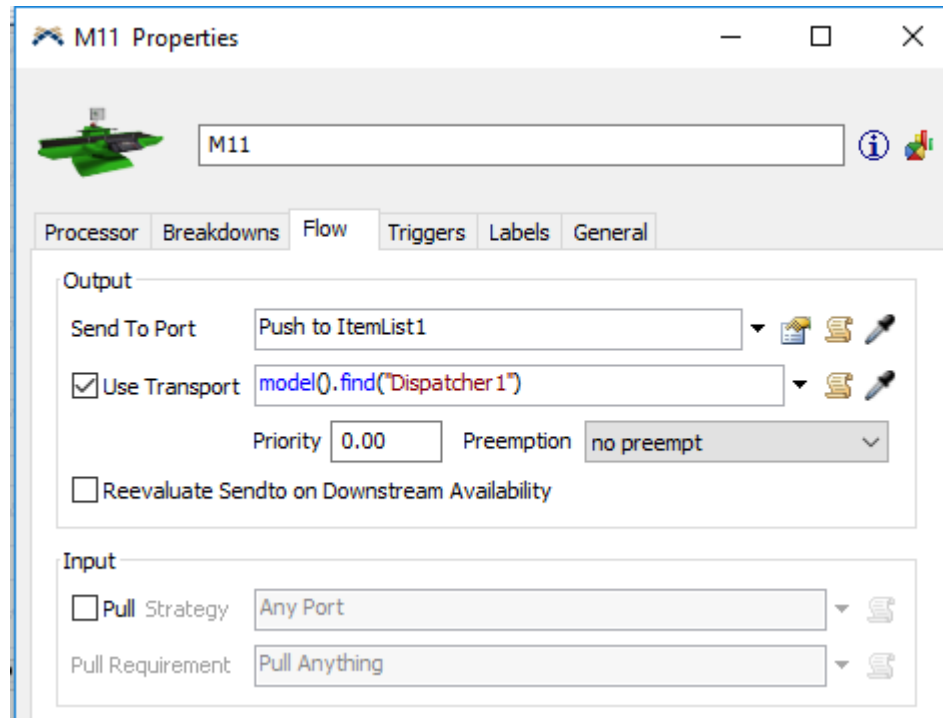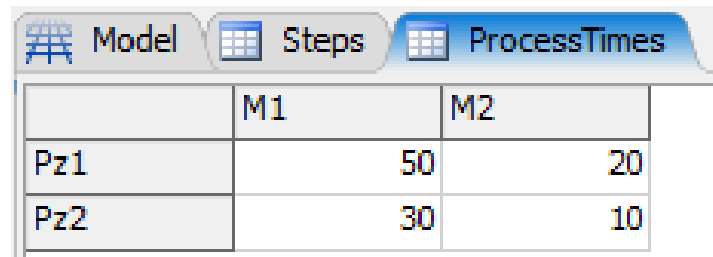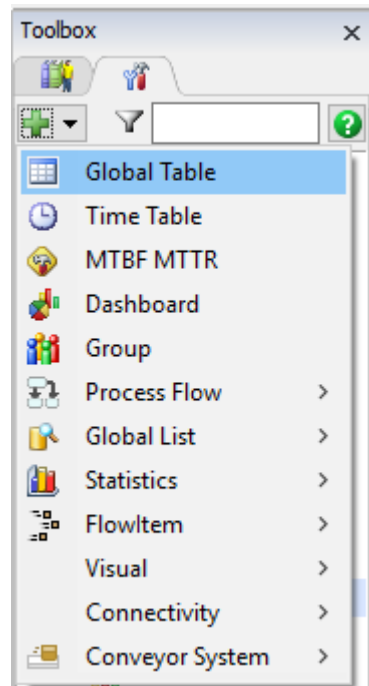
Tutorial 4

- In all processors, at the "Triggers" tab, click on the green plus sign and select "On Process Finish". Define a Label "Row" with the updated value equal to the following command:

getlabel(**item**, "Row") + 1
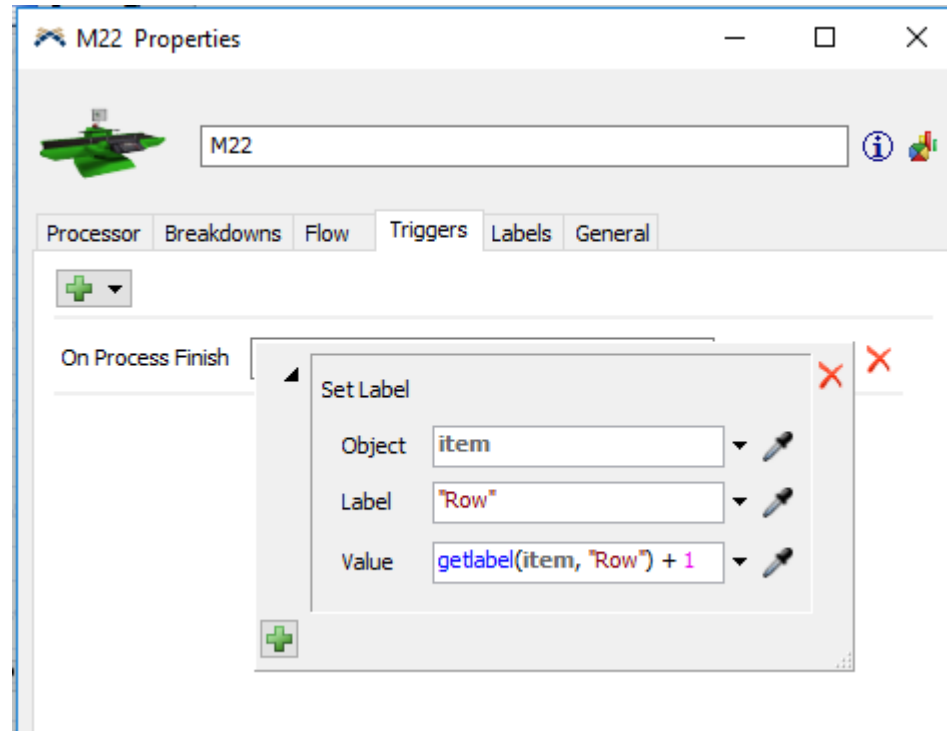
Tutorial 4

- At the Toolbox, click on the green plus sign and then on Global Table.

- In Quick Properties, change the name of the Global Table to "ProcessTimes". Modify Rows to 2 and Columns to 2, and then on the table change the names of the column and rows headings.

- Select all the cells of the table, press the secondary click and choose Assign data – Assign Number Data, and finally introduce the processing times in the table.

	M1	M2
Pz1	50	20
Pz2	30	10

Tutorial 4

- In all processors, at the "Processor" tab in the Process Time select "By Global Table Lookup".
- Change the table name to "ProcessTimes", the Row to item.type, and the Column to the respective machine type (i.e. 1, or 2).
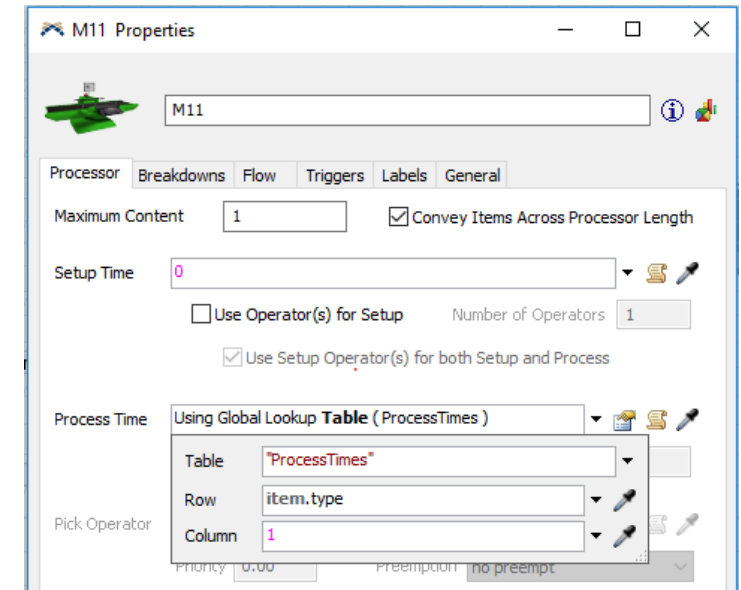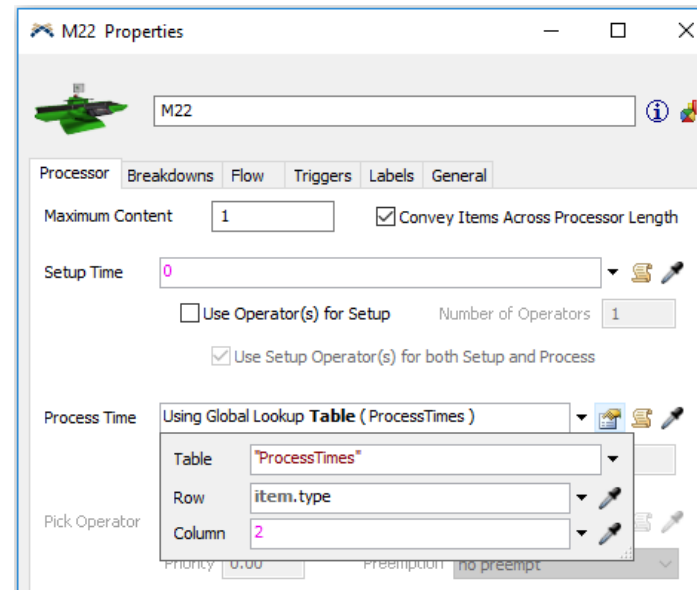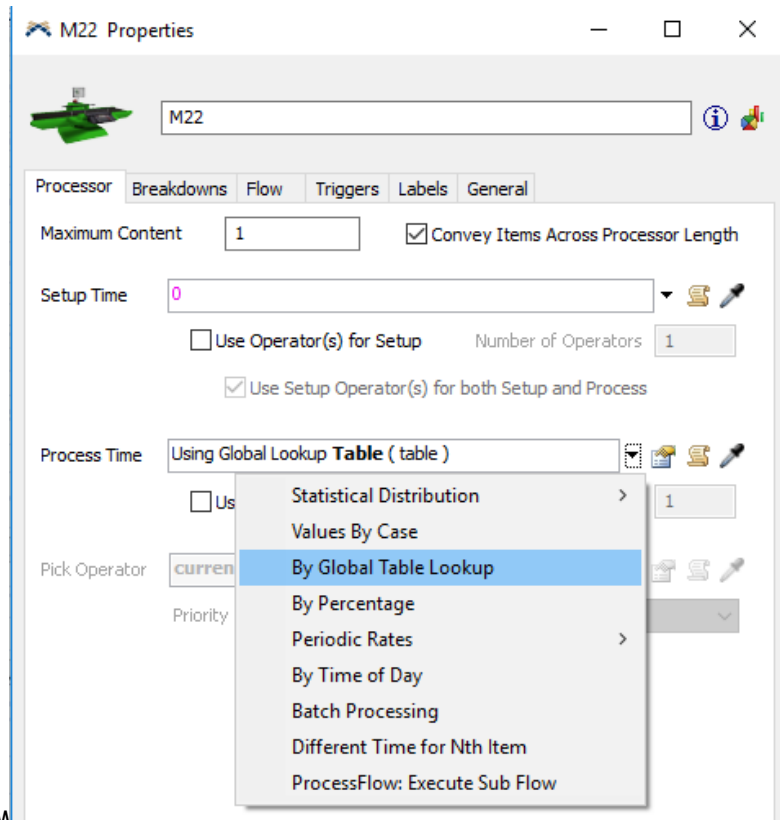
Tutorial 4

- Verify the connections among objects.
- Run the model to check for errors.

Tutorial 5

Important Concepts:

- Performance Measurement (i.e., Dashboard).
- Machine Failures (i.e., MTBF, MTTR).
- Group of Resources

- From the model developed in tutorial 4, we click on "Dashboards" then "Add a dashboard". A Dashboard window should open as shown bellow.

- Double click inside the Dashboard white window to open the available templates. Select "WIP By Type Vs Time" inside the WIP Templates, and set the values as follows:
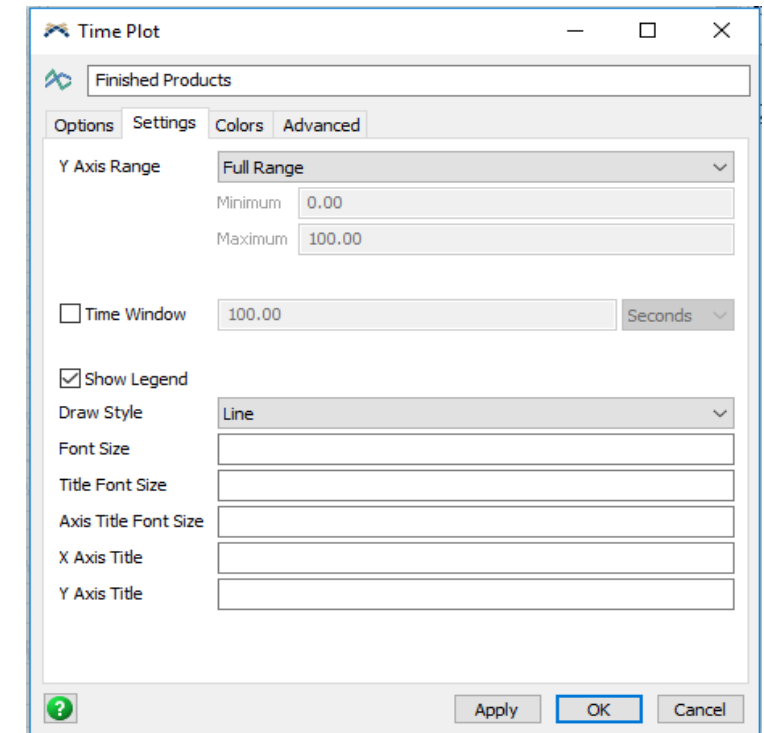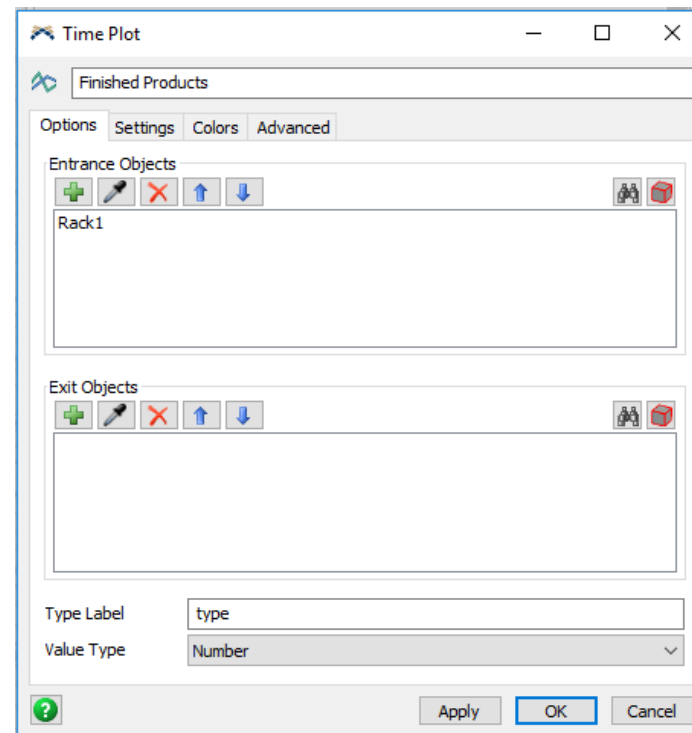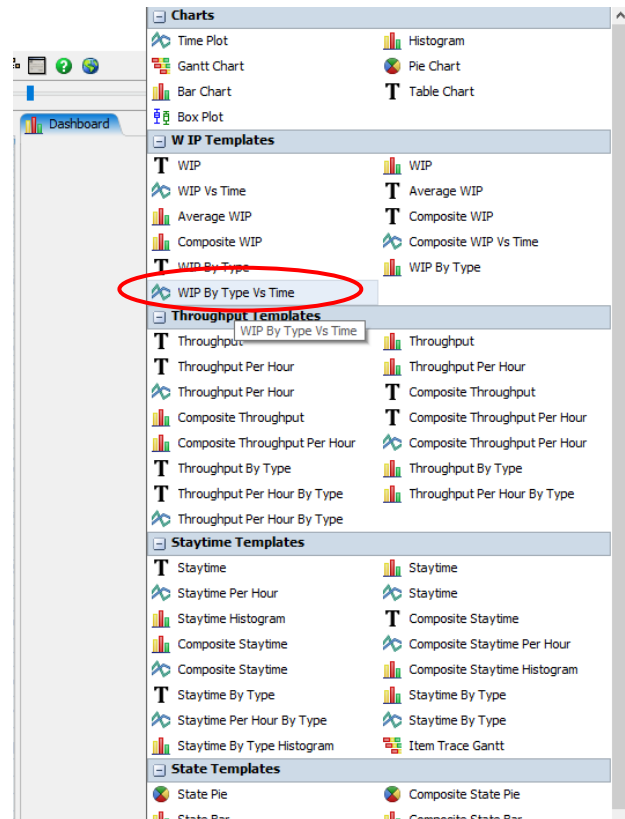
- Adjust the dimensions and location of the new plot in the Dashboard window with your cursor and black squares that delimit the plot.
- Click Reset and Run your model to see how the plot shows changes in real time.
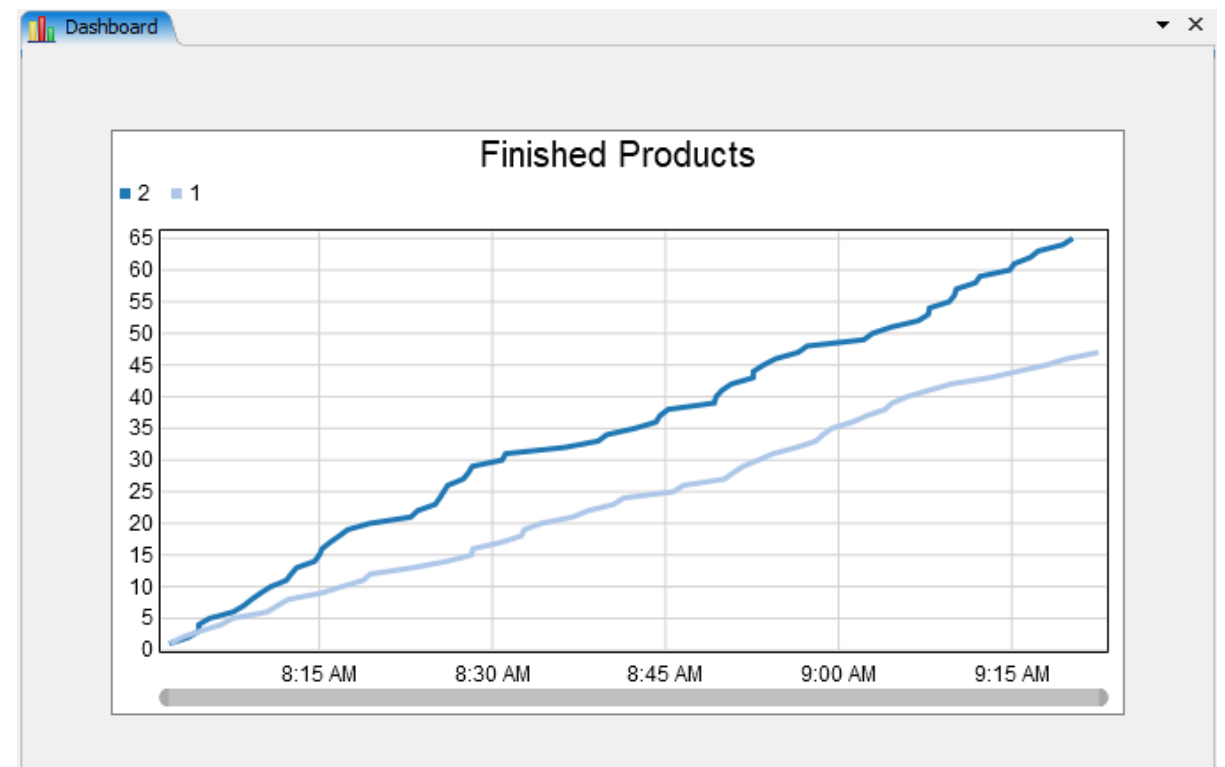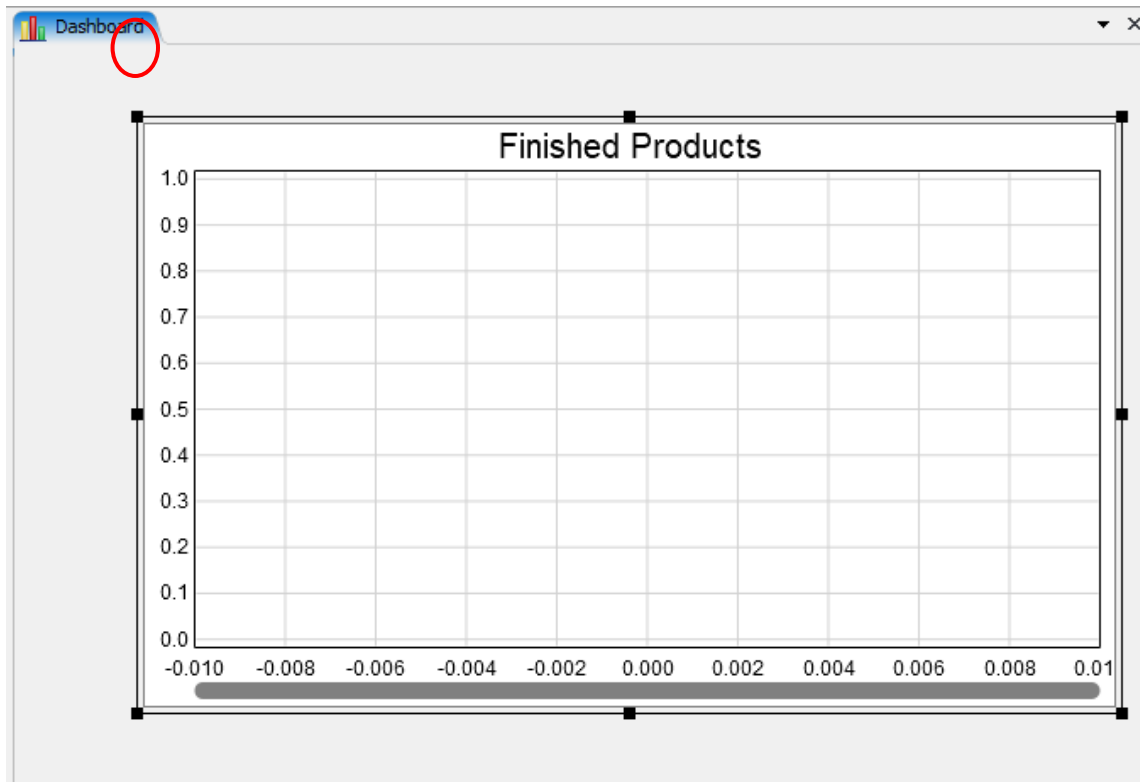
- Select Queue1, and click the   button at the "Content" statistics tab in the Quick Properties of the selected Queue1.

- Pin it to the Dashboard selection the Content option. A Content text table should appear in the Dashboard as shown bellow.

- Double click on the recently created Queue1 Content table, and click on the "…" button to open its properties. Then "sample" from the 3D model Queue2 and click ok.

- Reset the model and the Content Table should be updated as shown bellow.

Tutorial 5

- Repeat this exact procedure but now for the "StayTime" statistic of your Queues. Reset and Run your model, observe how this tables update in real time.
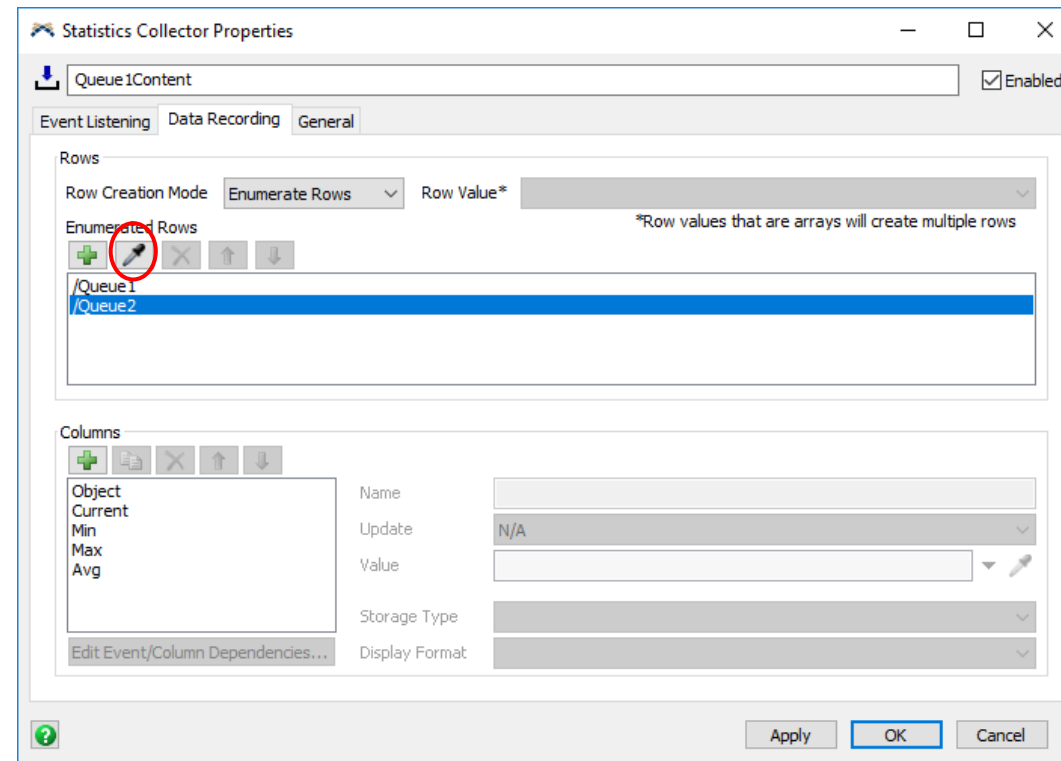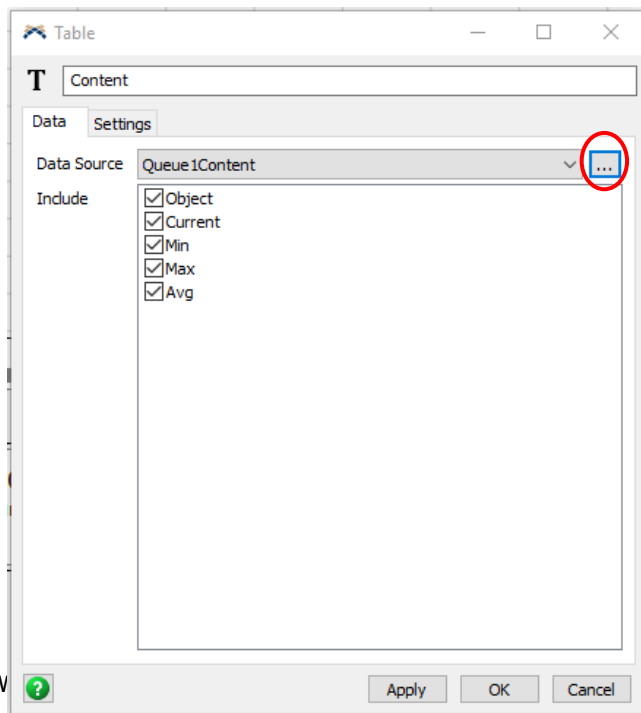
Content				
Object	Current	Min	Max	Avg
Queue1	124.00	0.00	125.00	58.04
Queue2	61.00	0.00	62.00	28.49

Staytime			
Object	Min	Max	Average
Queue1	2.36	1192.55	565.79
Queue2	1.98	581.47	335.70

- In the Toolbox, select the "Group" option. Create one group for each type of machine (name the groups accordingly), incorporating the respective members, sampling from the 3D model, into the groups.
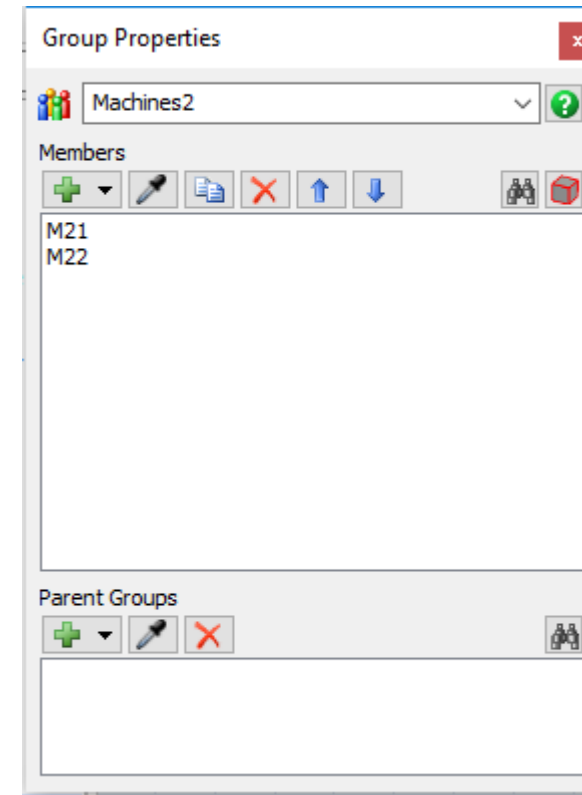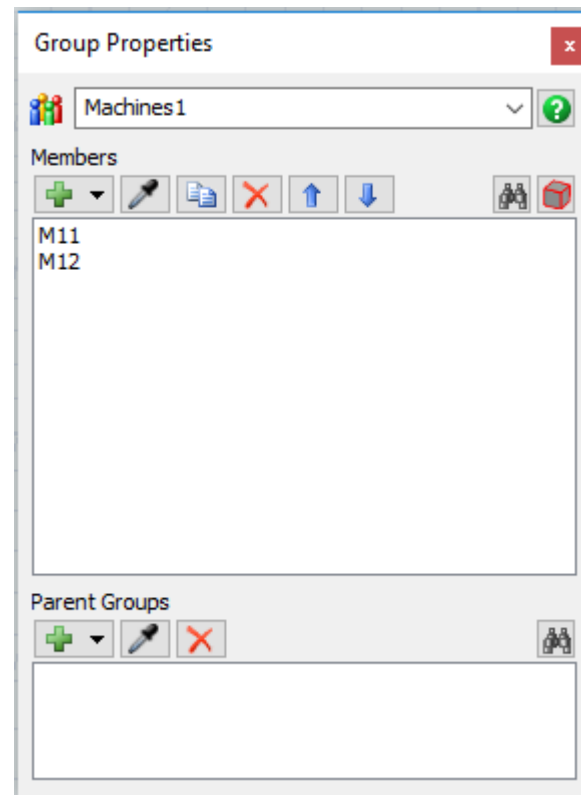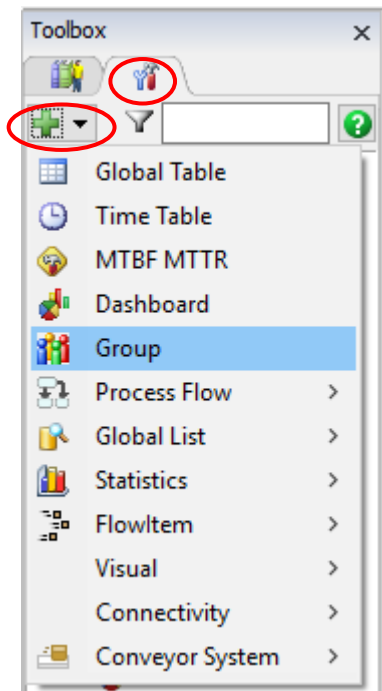
Tutorial 5

- In the Toolbox, select the "MTBF MTTR" option. Incorporate the members by looking into the groups or by directly sampling from the 3D model.
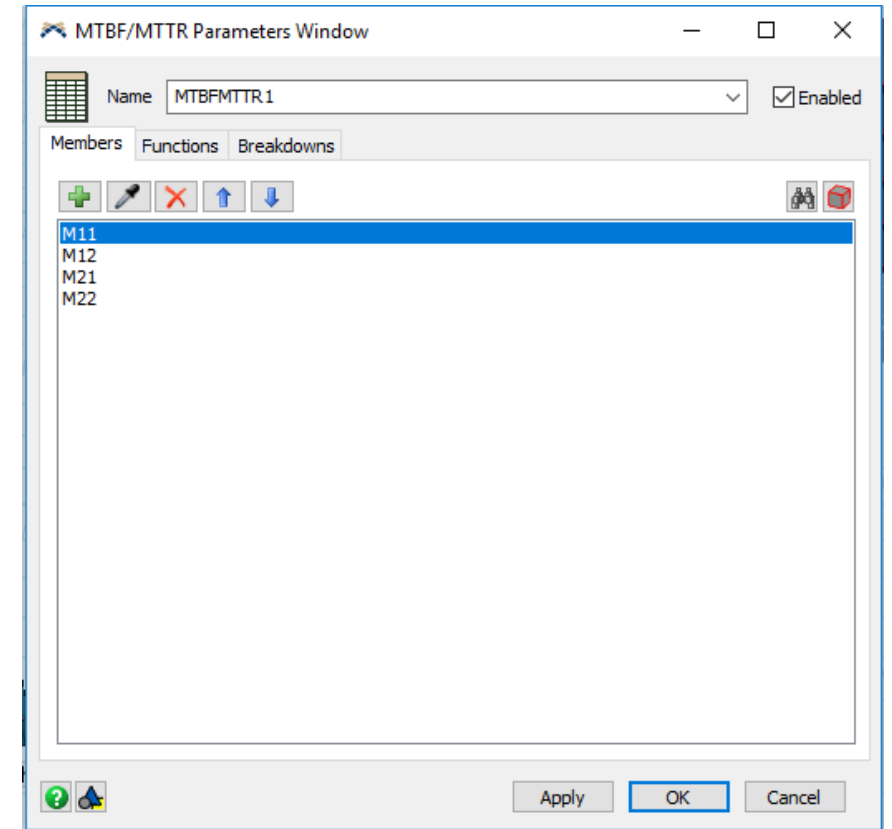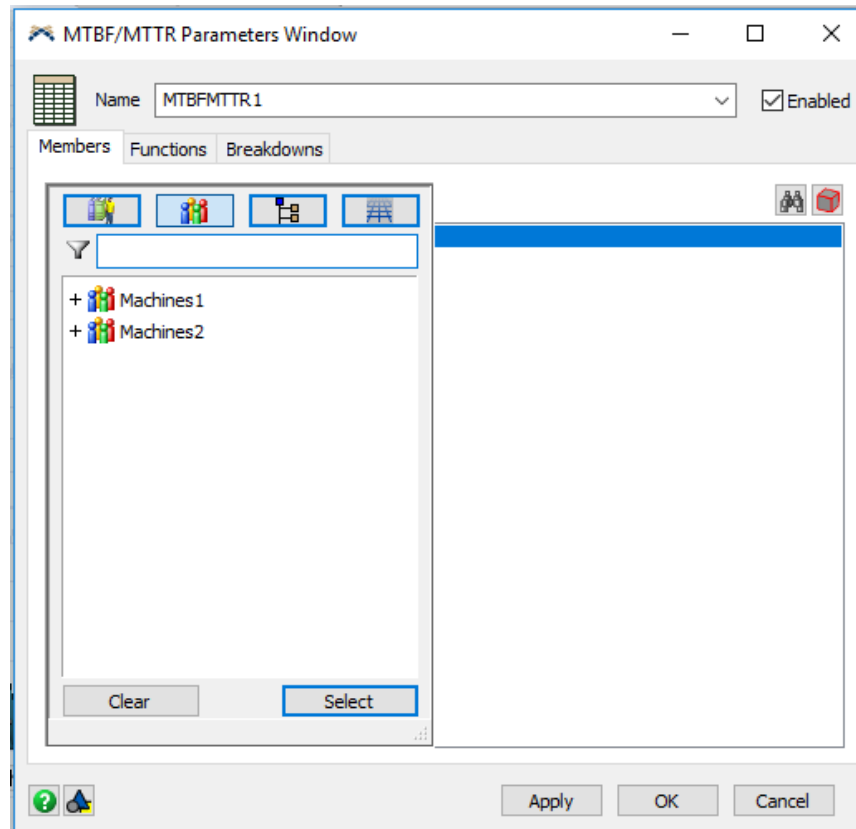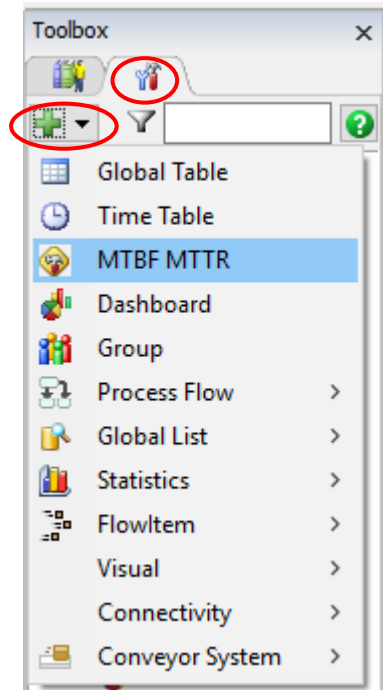
- At the "functions" and "breakdowns" tabs, insert the respective properties as shown below.
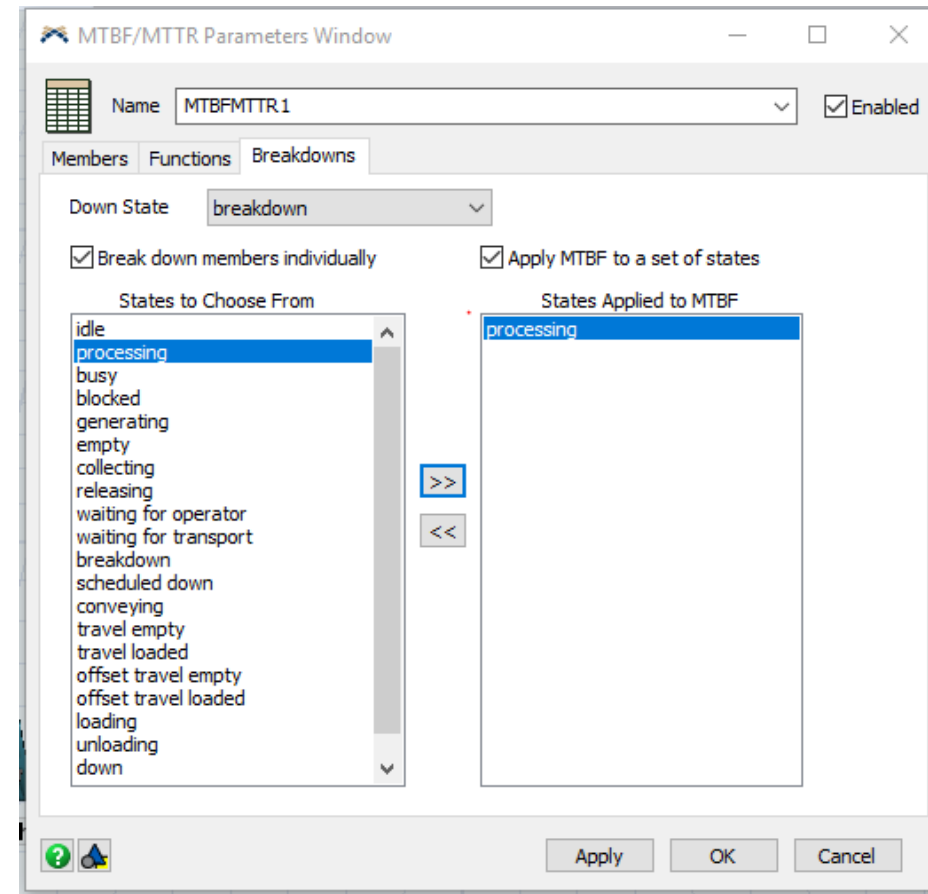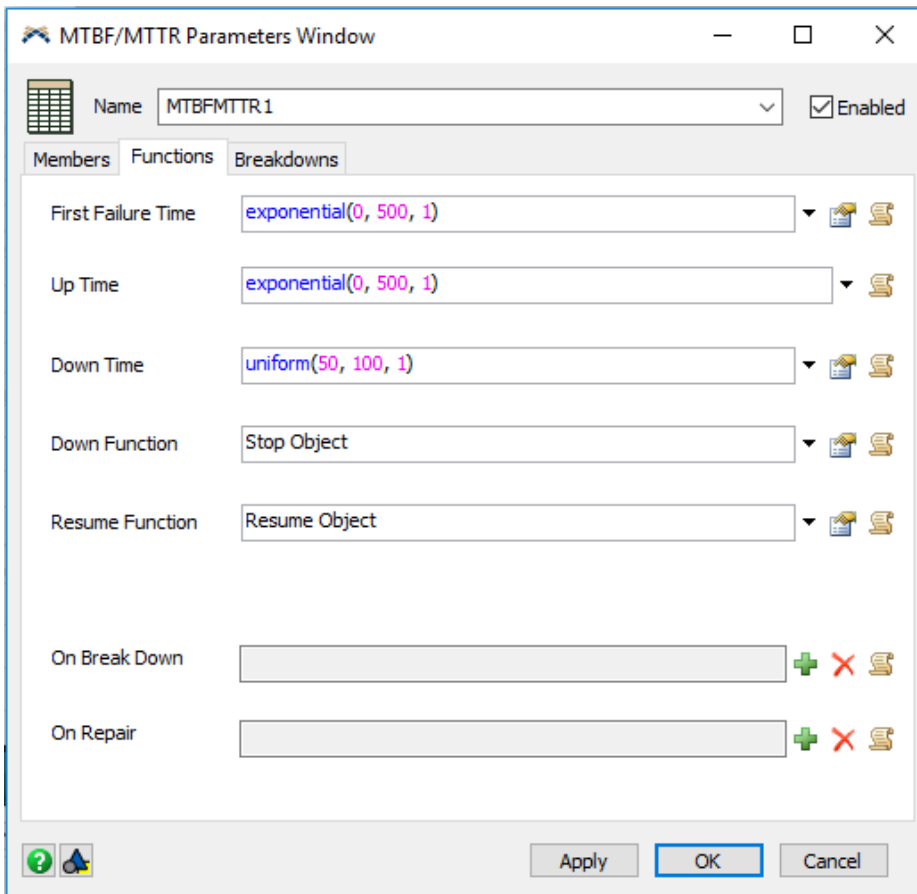
- Double click at the "Dashboard" window to open the available templates, within the "State Templates" select "Composite State Pie".

- Double click on the plot that appears to open its properties, at the Objects window click on the   sign and the choose "Groups" + "Machines1"
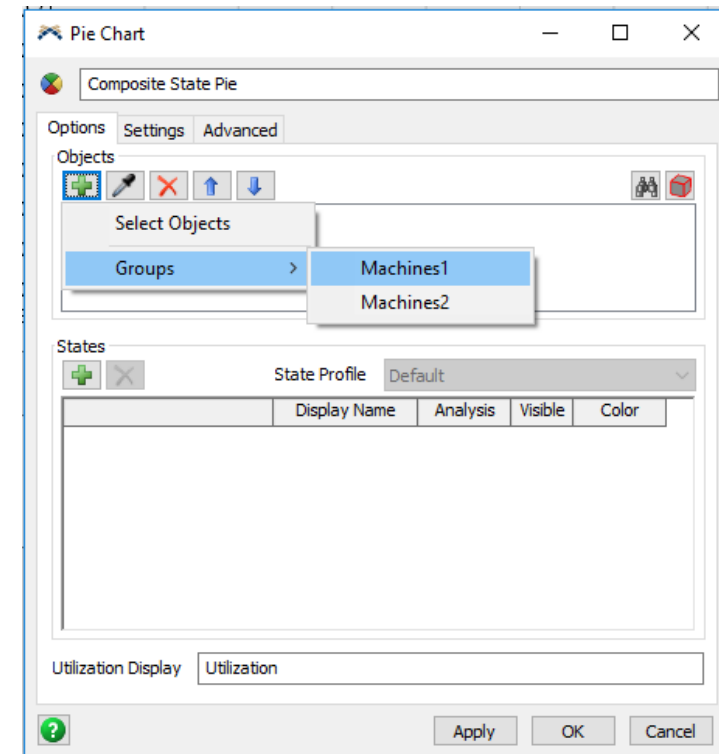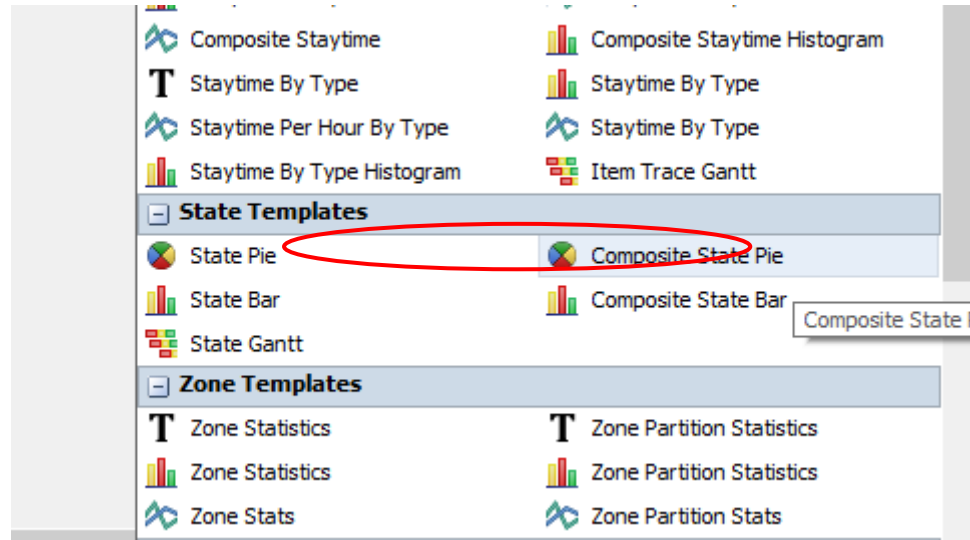
- When an object is selected, the list of states appears on the window bellow. By clicking on the color bar for each state you can modify them as you whish. *Note: make it a visual aid (e.g. blocked = red, processing = blue, or green).*

- Change the name of the plot to "Machines Type 1"
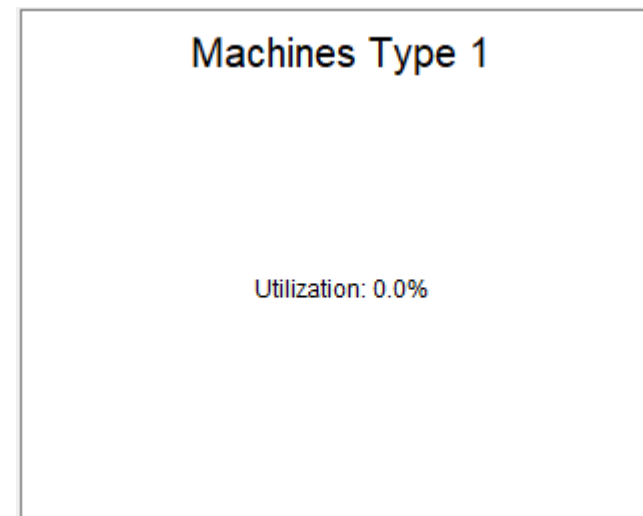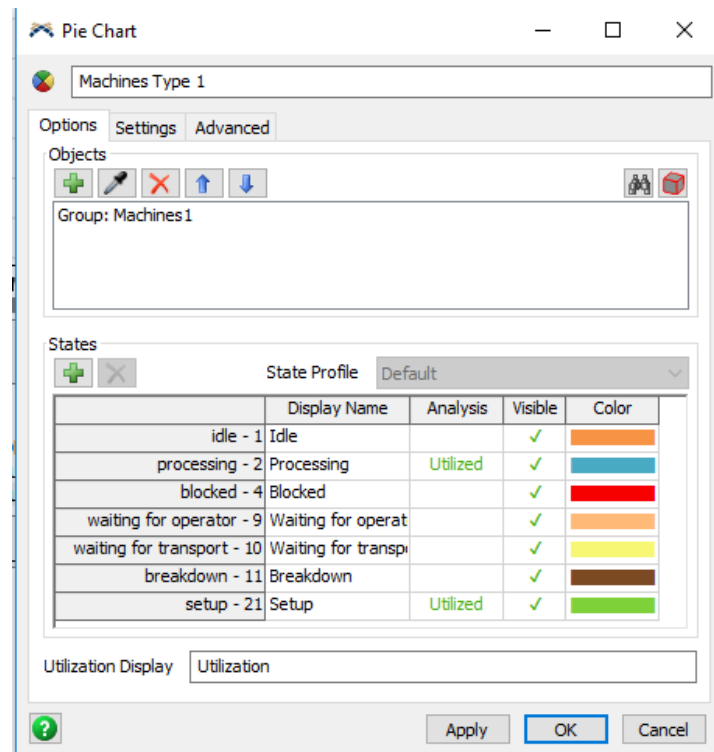
- Repeat all this process again for Machines Type 2, reset the model and run it to see how the plots react in real time.
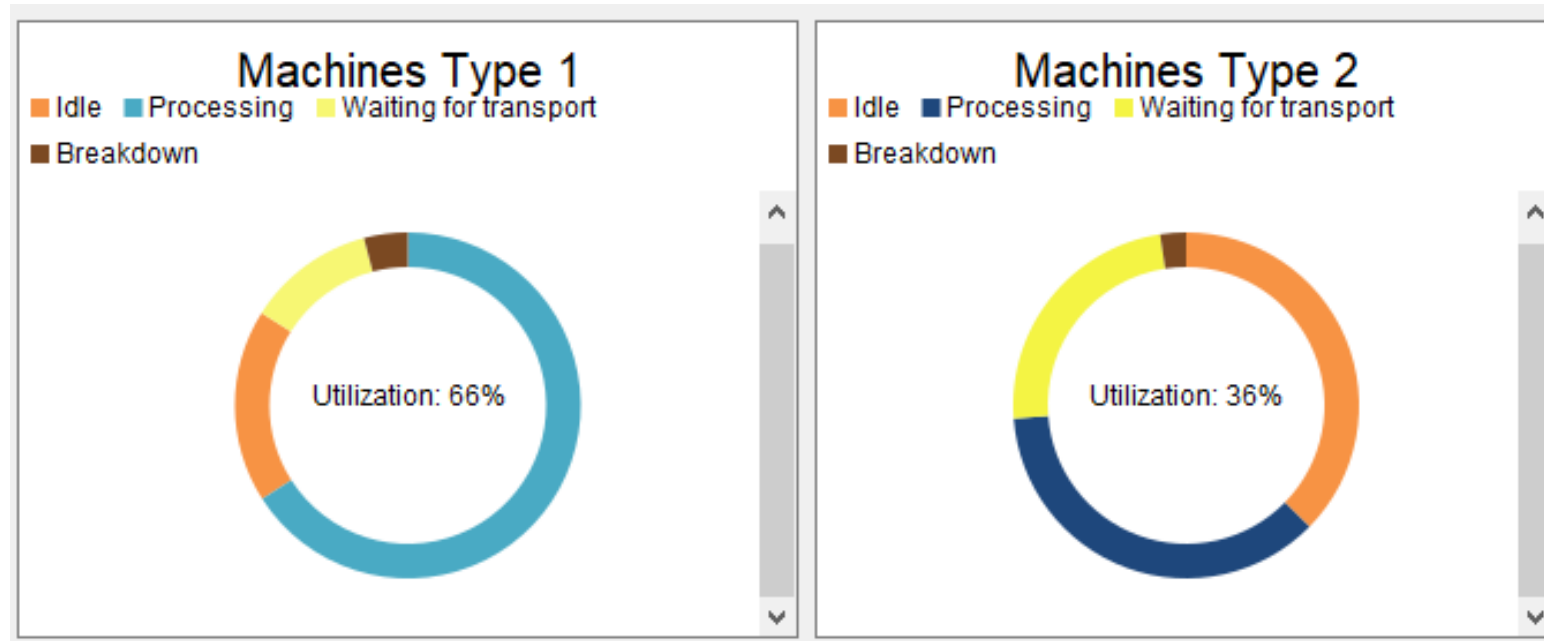
- Double click on the "Dashboard" white window to select the "Financial Analysis".
- Add both machines groups as object members.
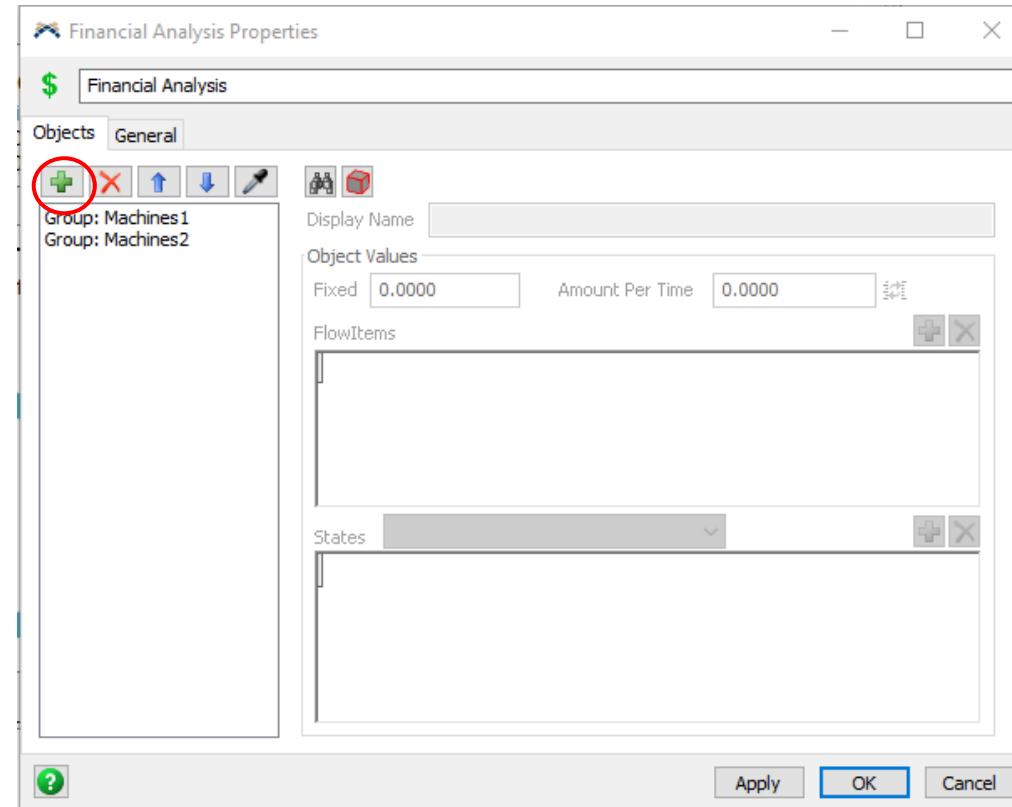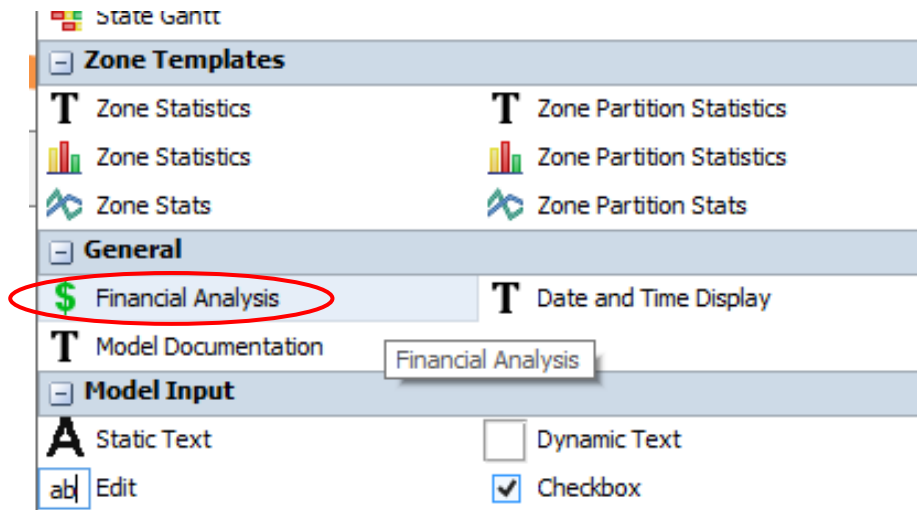
Tutorial 5

- Select one by one the Machines Groups to make their cost properties available, then add the Fixed and States-based cost values as shown bellow. At the general tab change the Currency to "Euros".
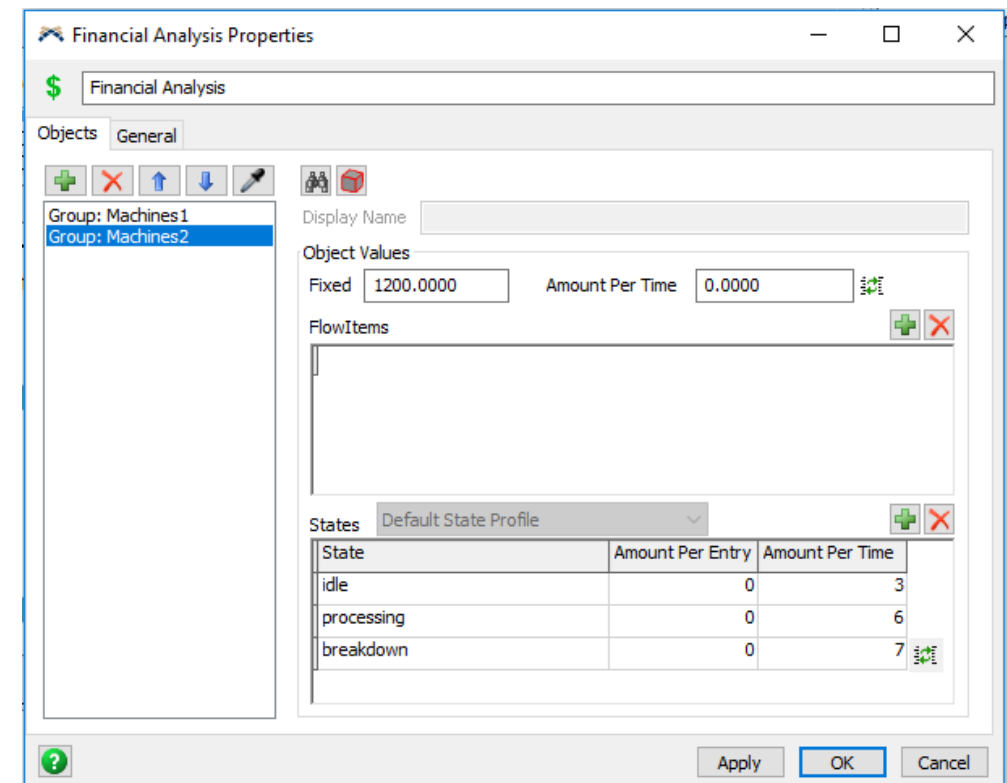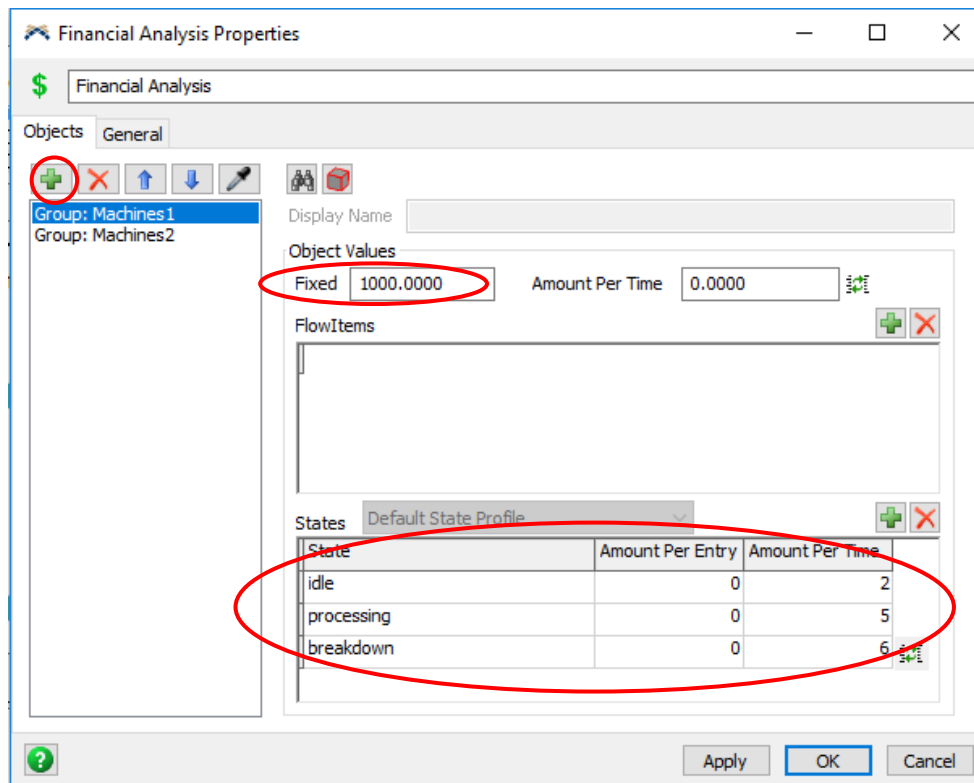
- Reset and run the simulation to observe how the cost behaviour is depicted as the operation of the machines progresses.

Financial Analysis	
▷ **Totals**	**€80.890,41**
Fixed	€4.400,00
Time	€0,00
State Fixed	€0,00
State Time	€76.490,41
Flowitems Fixed	€0,00
Flowitems Time	€0,00

Tutorial 6 – Design of Experiments

Important Concepts:

- Design of Experiments

- From the model developed in tutorial 5, we click on "Statistics" to open the Experimenter window.
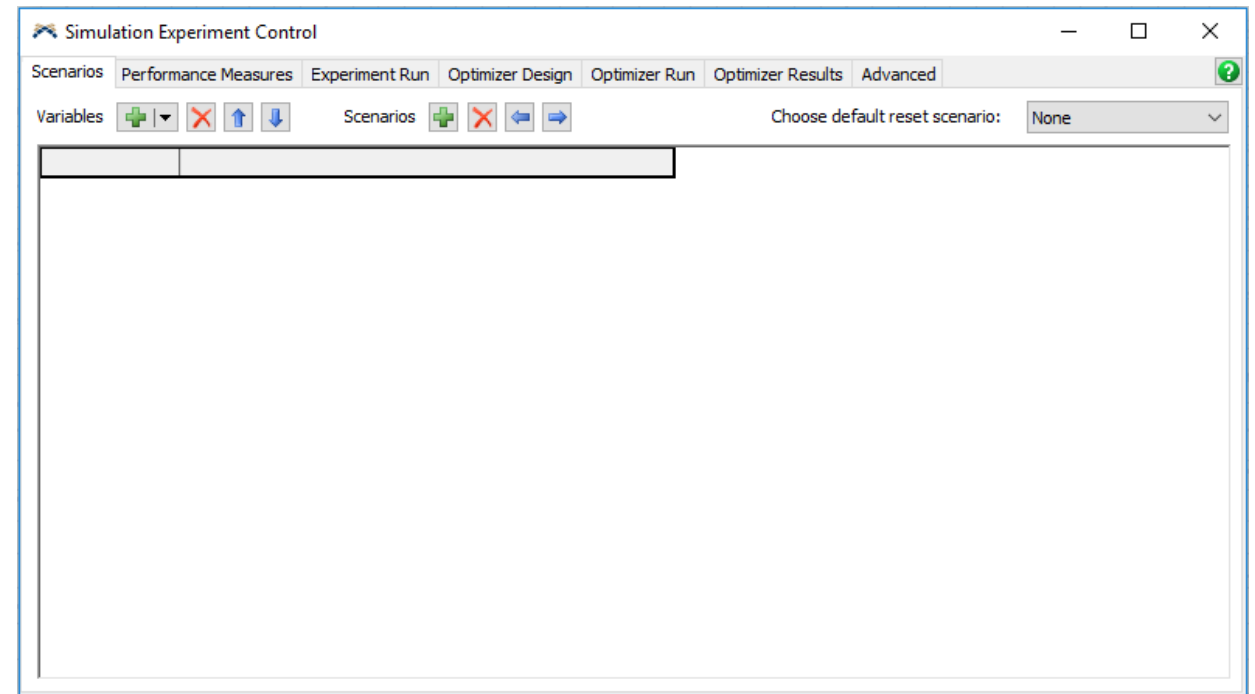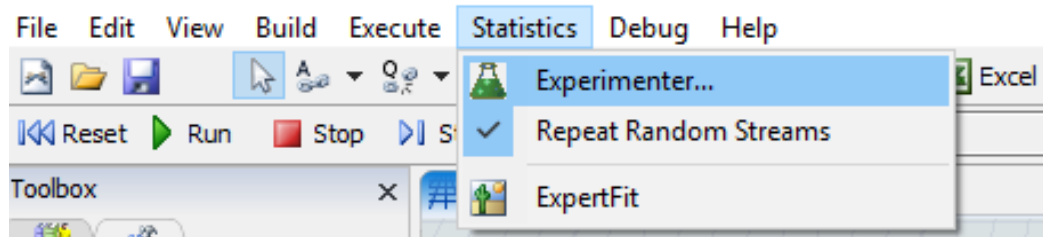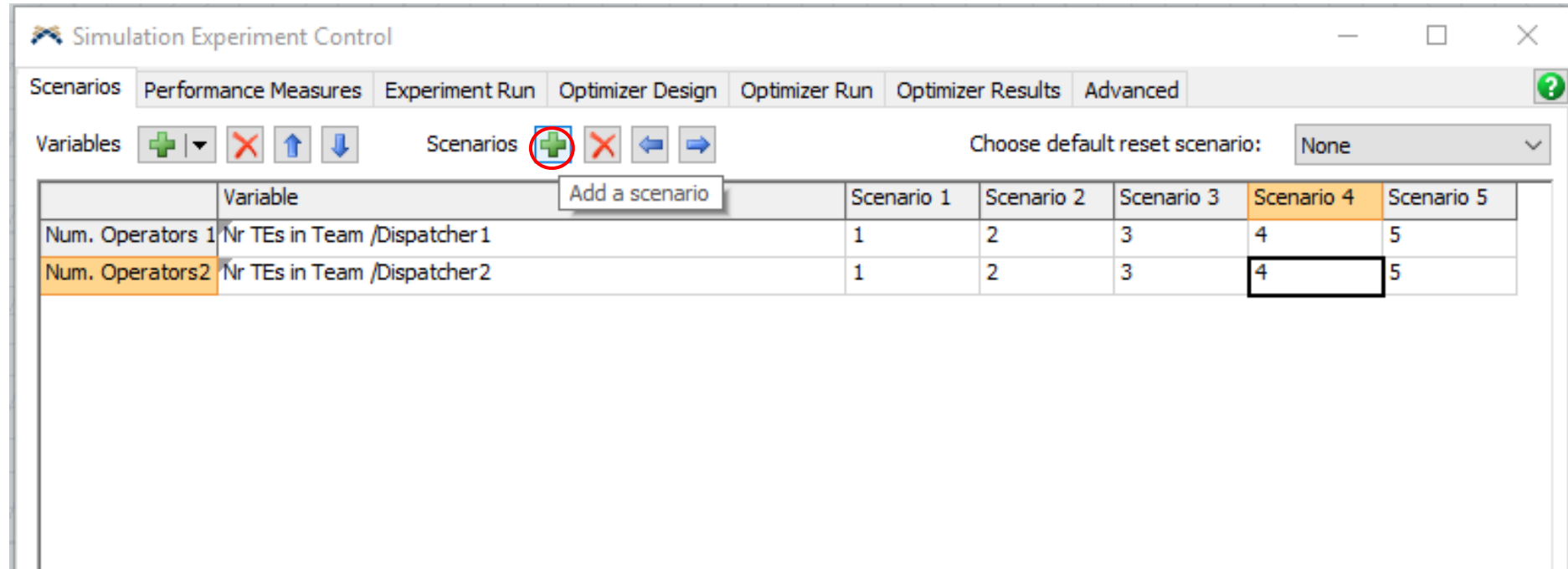
Tutorial 6

- We add a "Number of Task Executers" variable at the "Scenario" tab by clicking on the green plus sign – black arrow.
- We name the variable: Num. Operators1 choosing the team "Dispatcher1"
- We repeat this for Operators 2, selection its corresponding dispatcher.
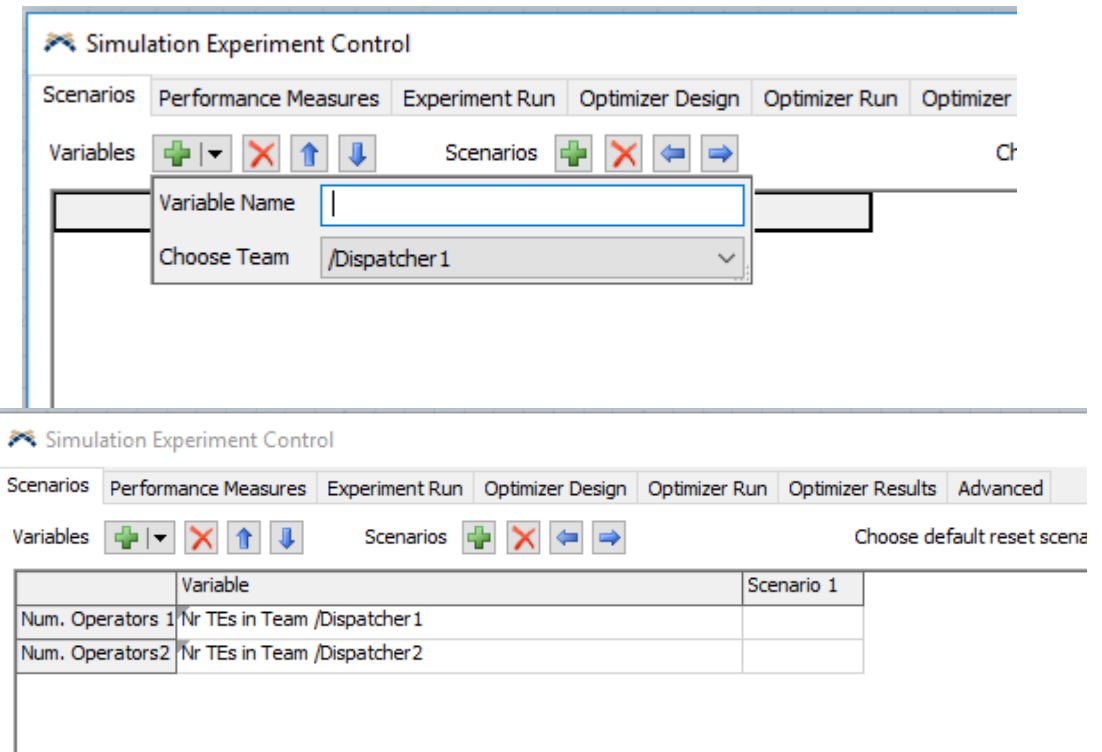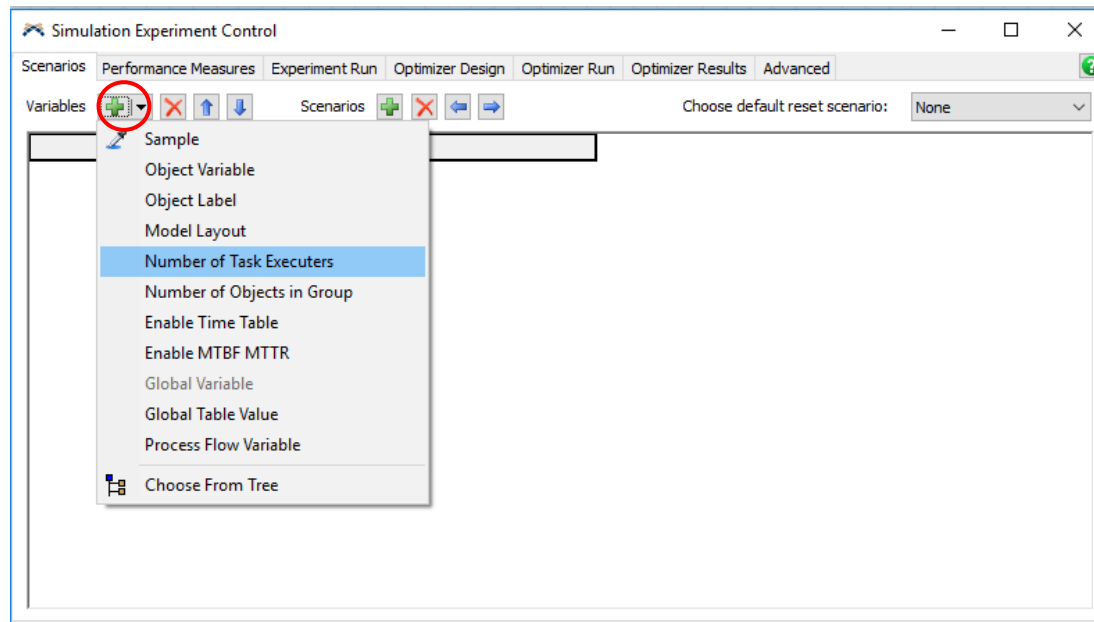
- We define the scenarios by clicking on the green plus button and entering the respective number of operators.
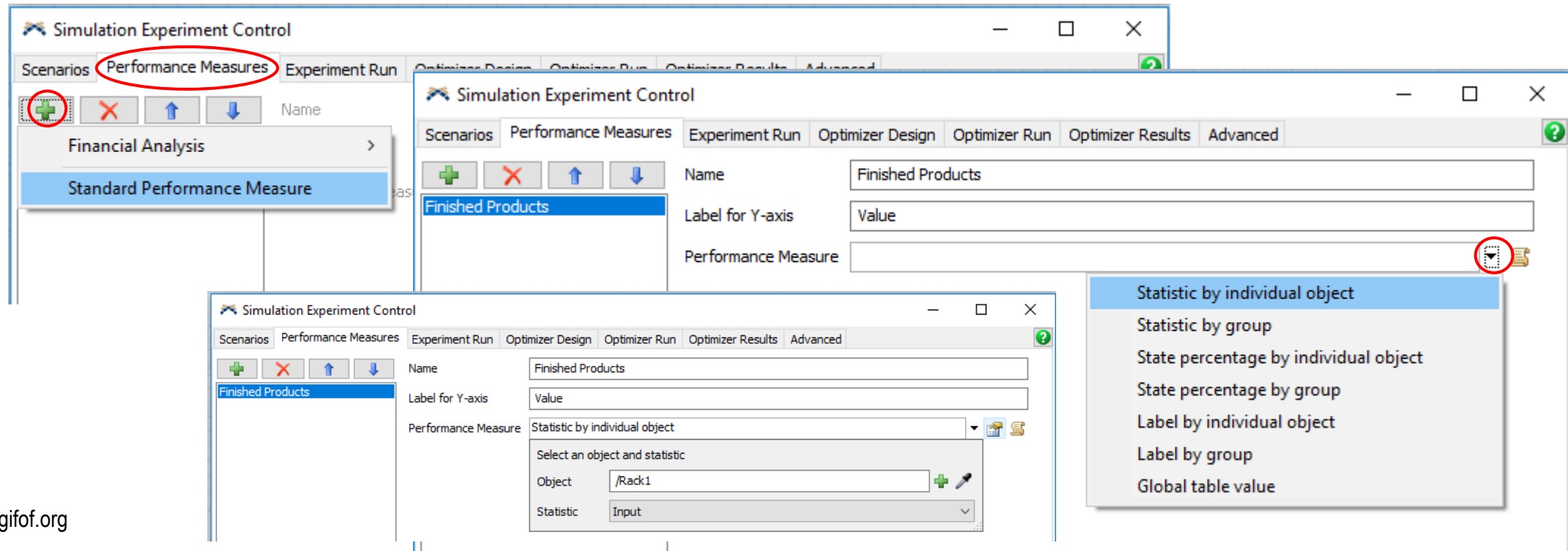
Tutorial 6

- In the Performance Measurement tab, click on the green plus sign to add a "Standard Performance Measure".

- Name the measure as "Finished Products" and select the "Statistic by individual object" – object = /Rack 1 and Statistic = Input.

Tutorial 6

- Create a new variable as explained before, selecting the following properties:
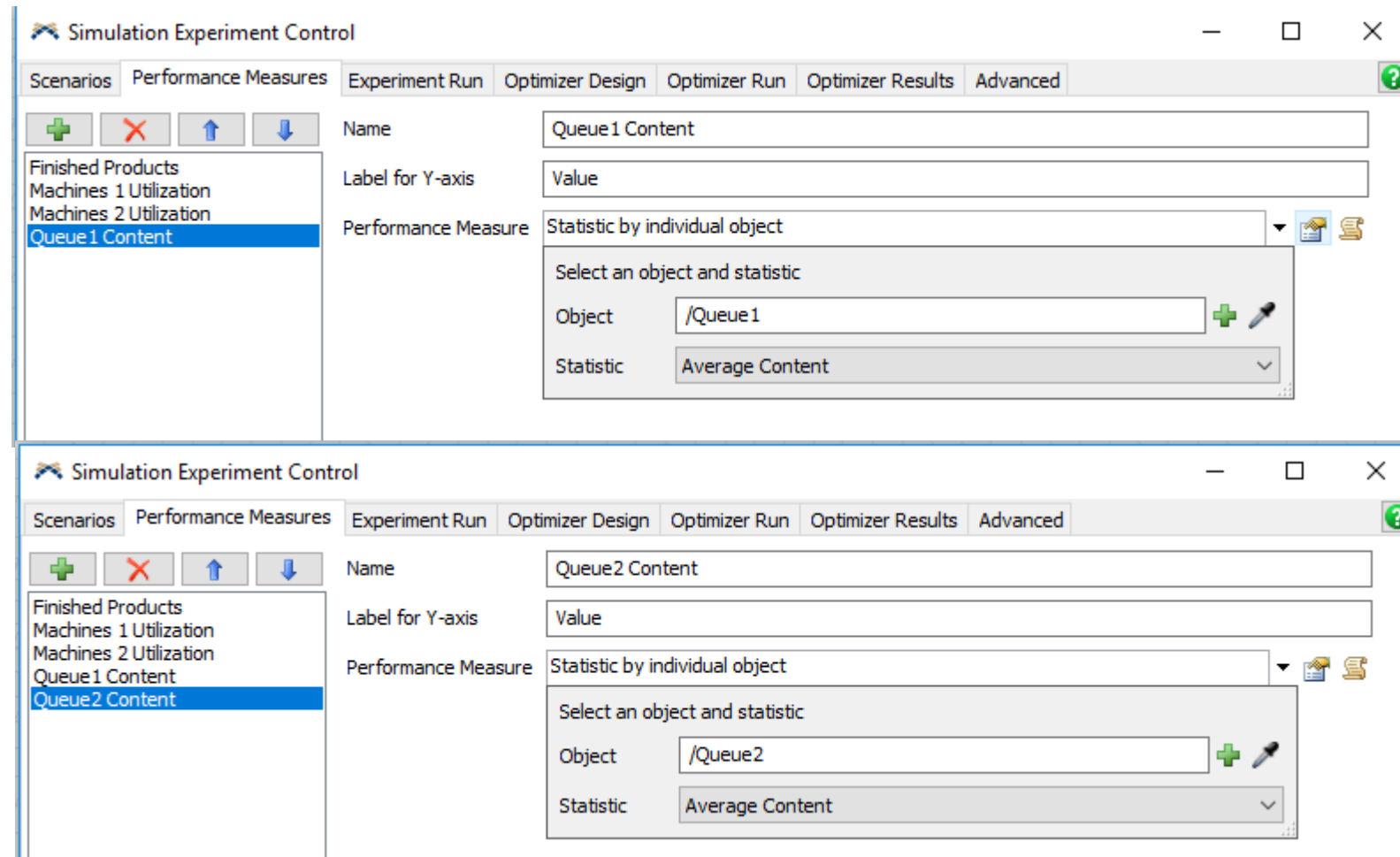
Tutorial 6

- Repeat previous process now for Machines 2:
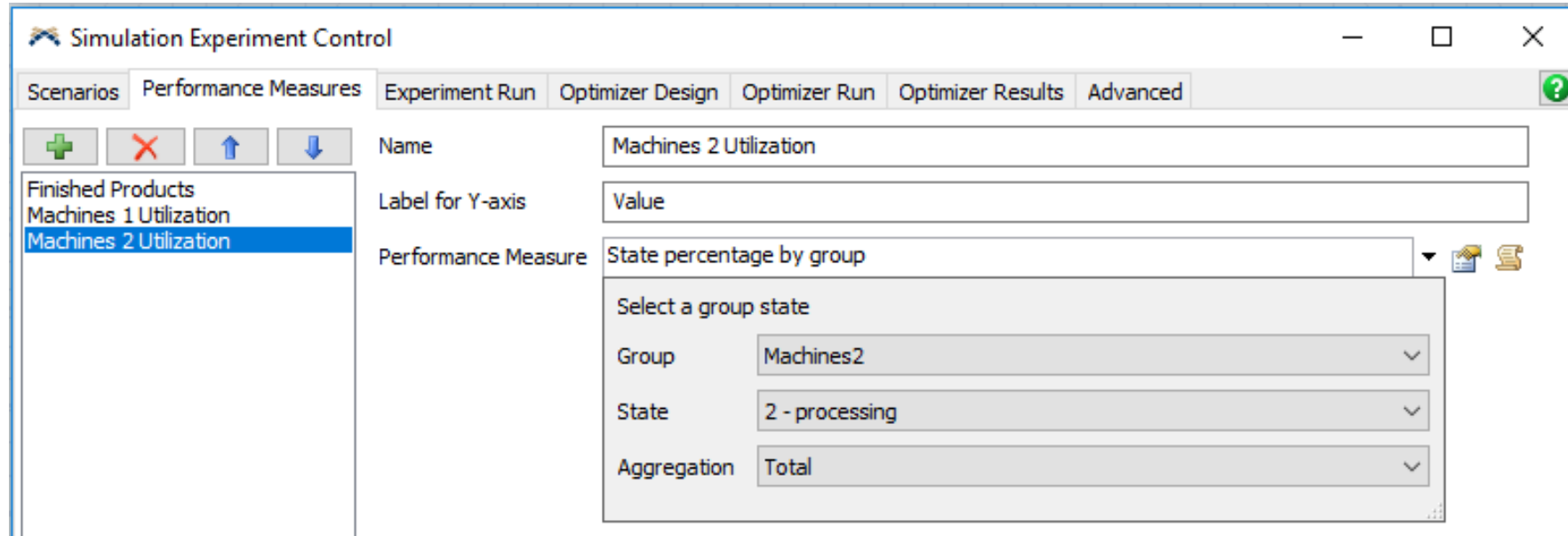
Tutorial 6

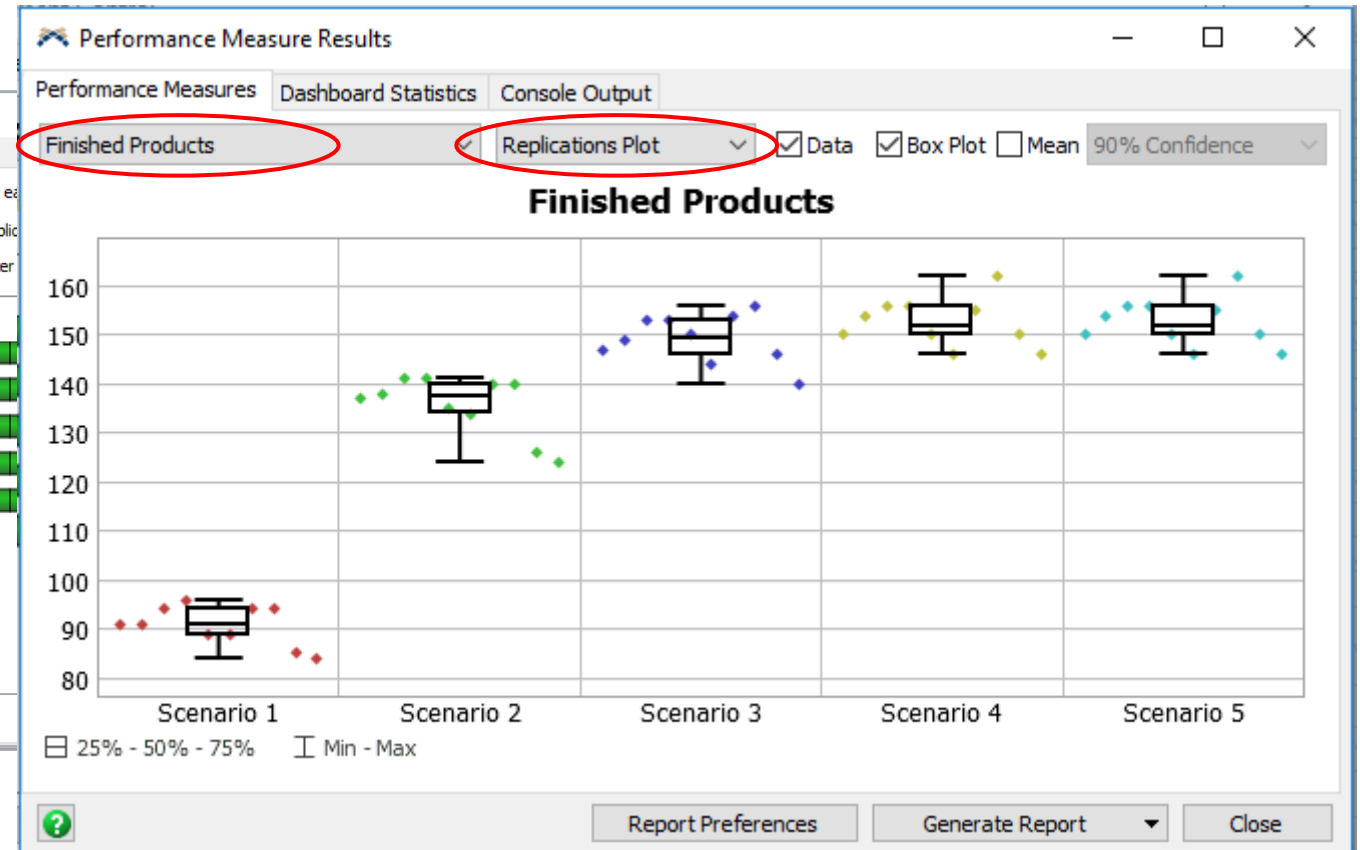- Define a new measure for both Queues as presented as follows:

Tutorial 6

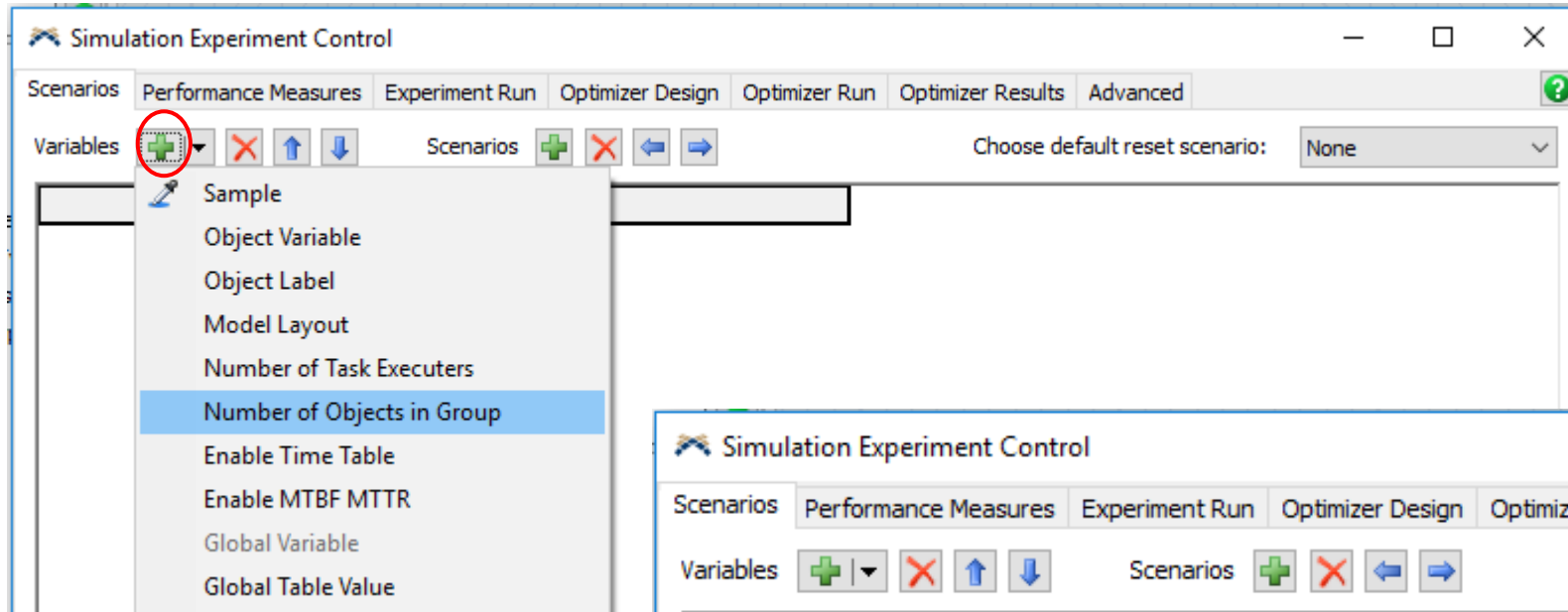- Finally define a "Financial Analysis – Total" Measure:

Tutorial 6

- At the Experiment Run tab, define 10 replications per Scenario, with a Run Time of 5000; click on the "Save dashboard data for each replication".
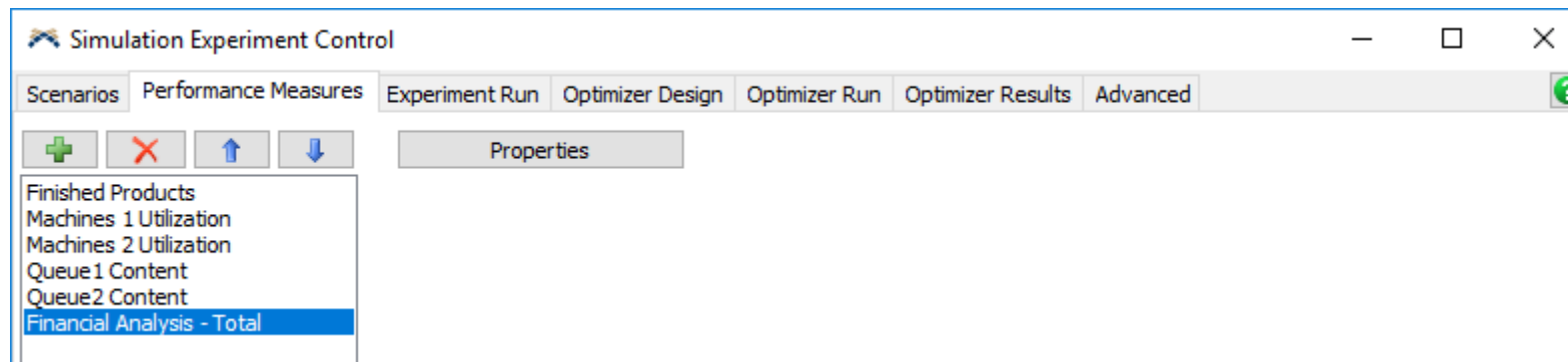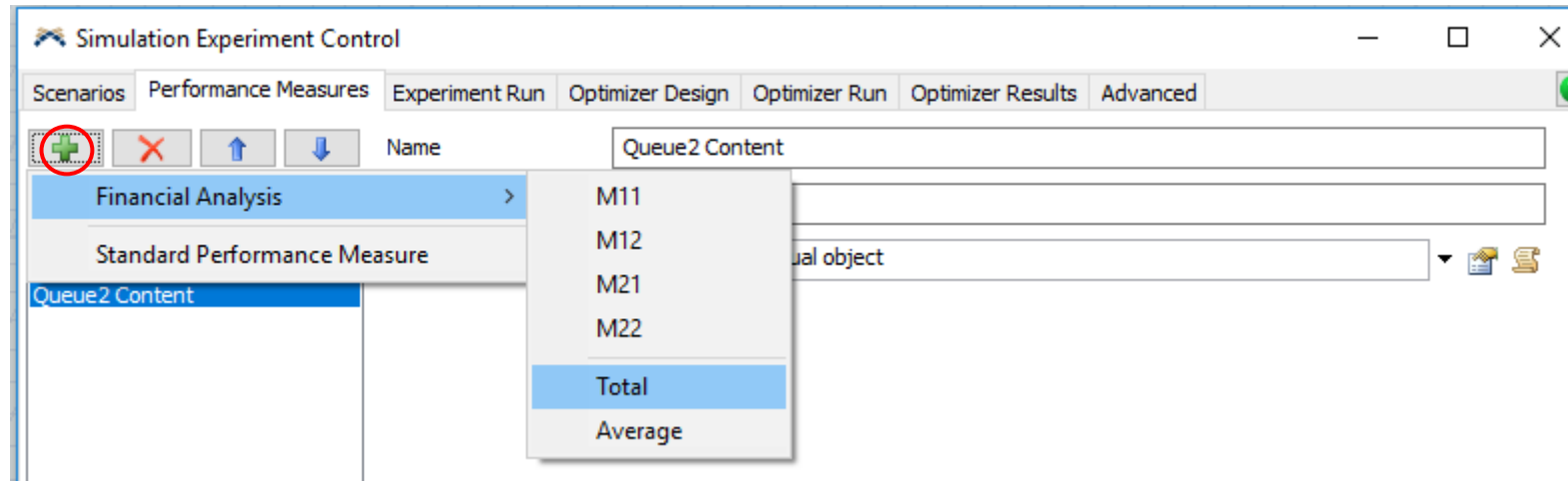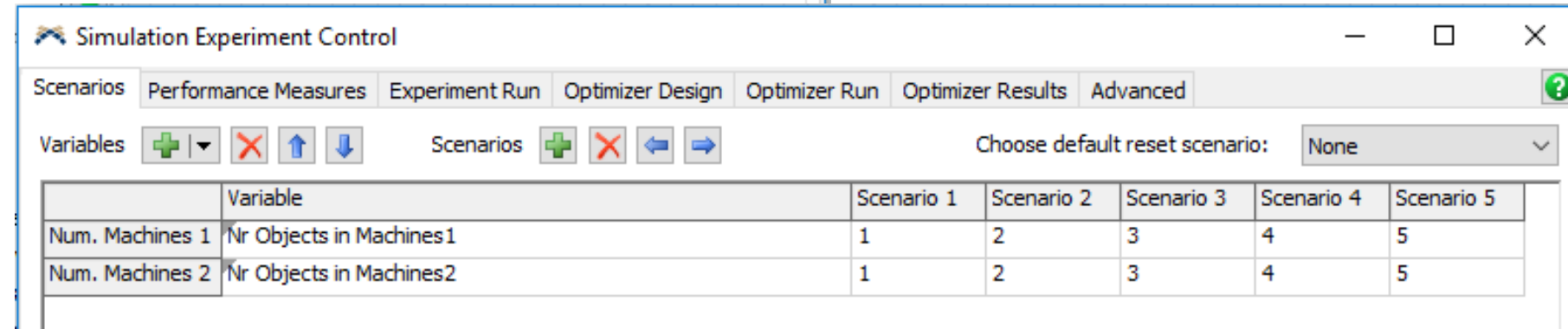
- Click on "Run the Experiment".

- Click on "View Results" and explore the performance variables and plots to observe the results of the experiment.
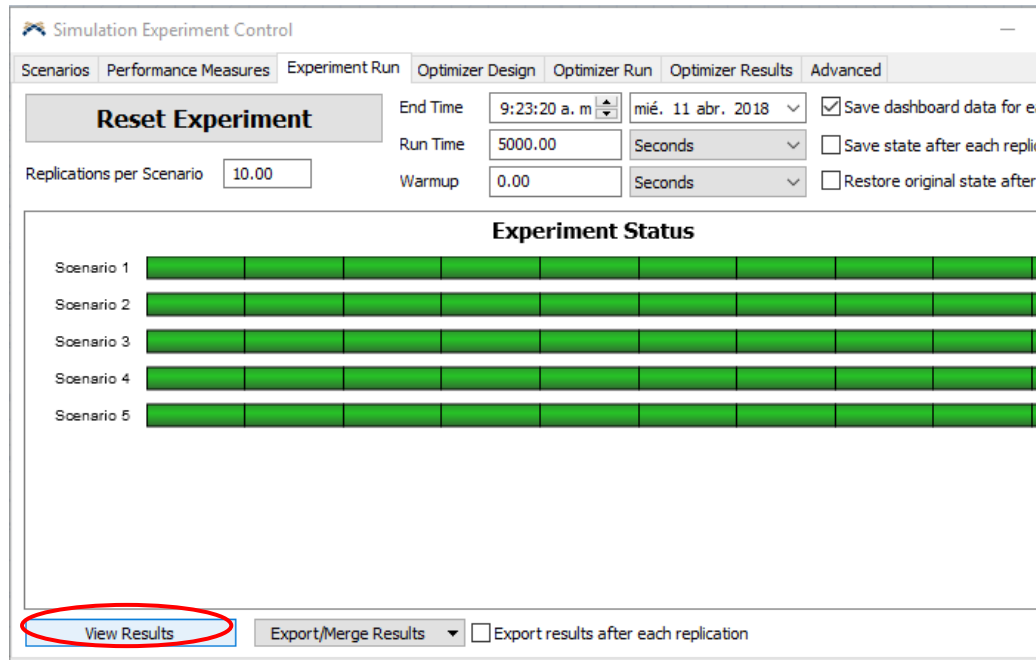
- Go to the Scenarios tab and delete current variables. Create the following ones:

Tutorial 6

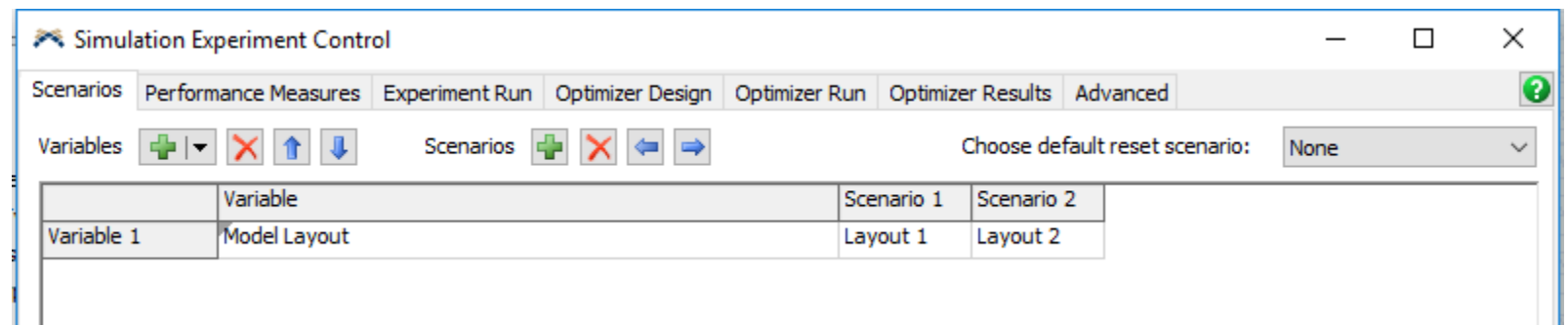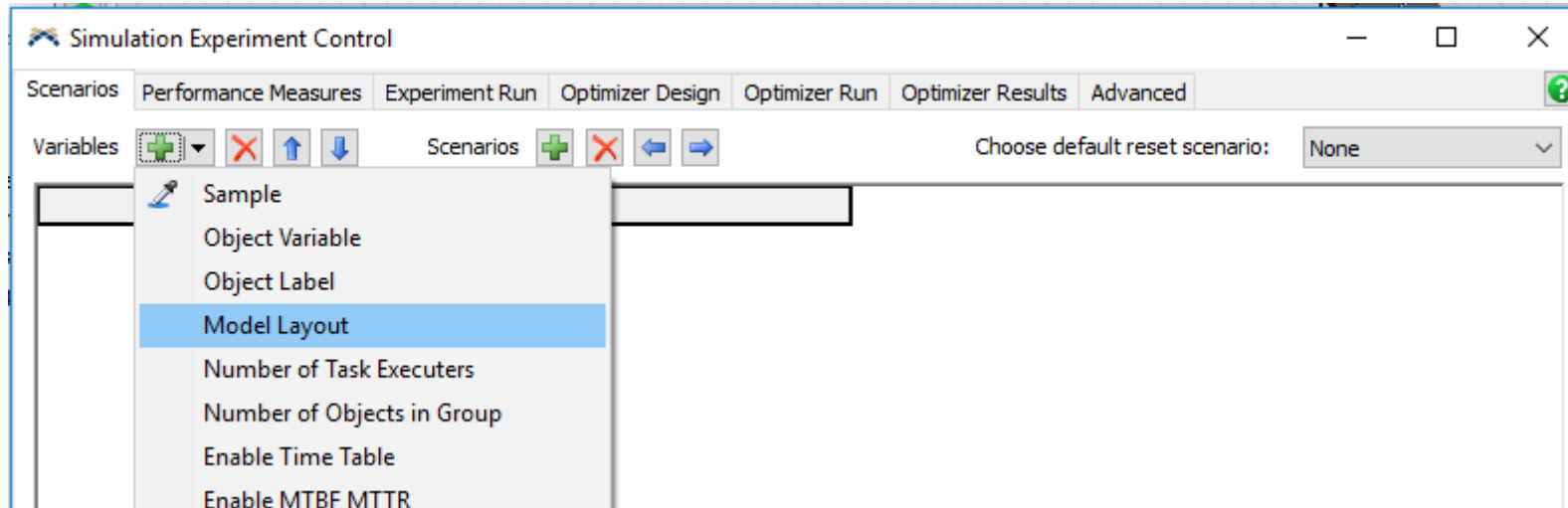- Reset and Run again the Experiment and explore the results.

Tutorial 6

- At the "View" tab in the main toolbar click on.

- At the "Model Layout" click on "Add Layout" and then on "Set".

- In you 3D Model move the "Queues" and the "Rack" for the operators to travel more distance; then select "Add Layout" and then on "Set".
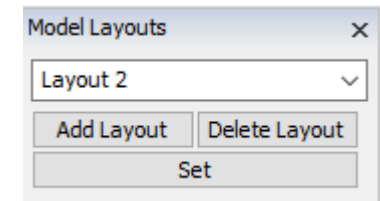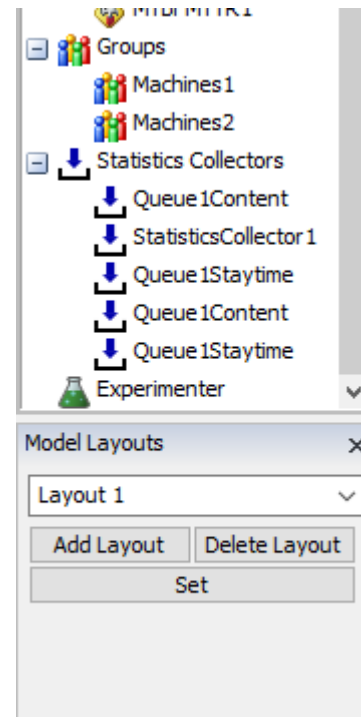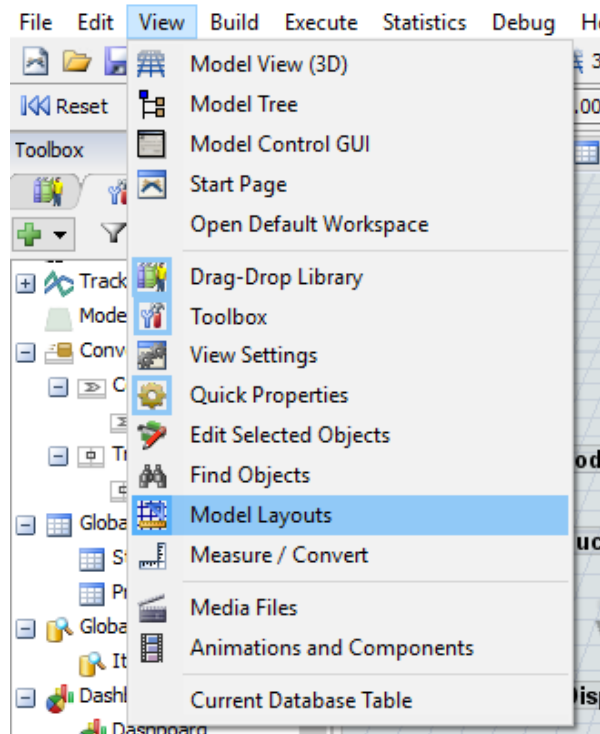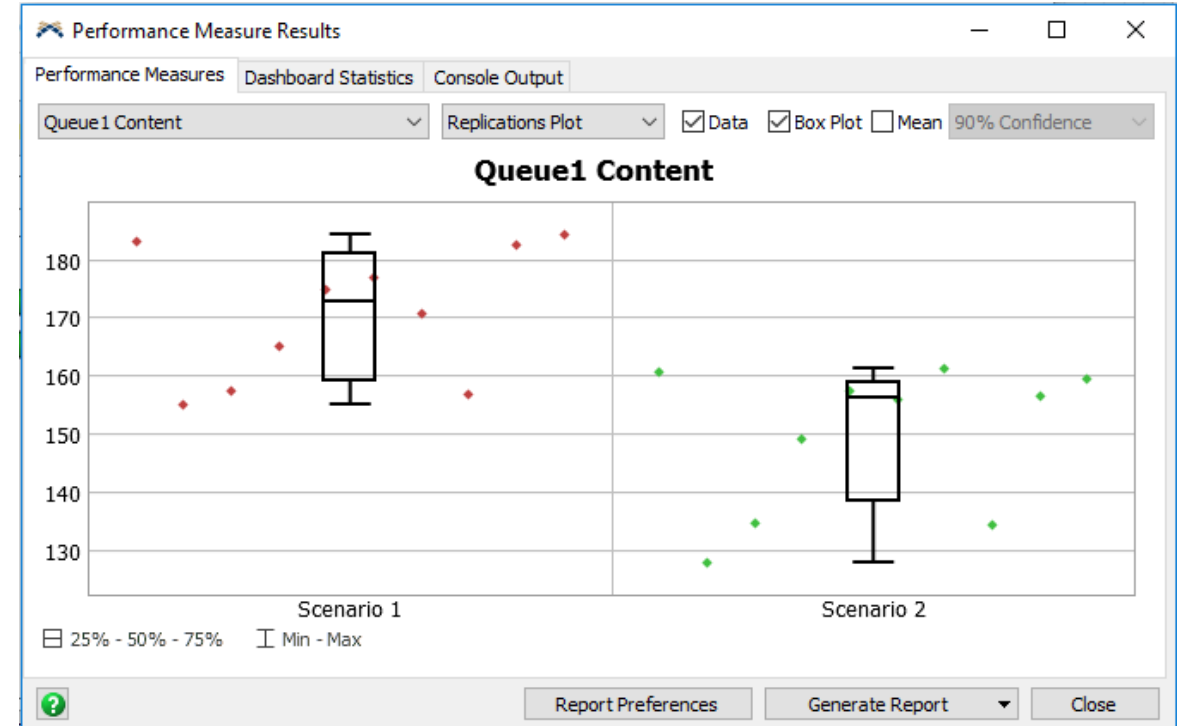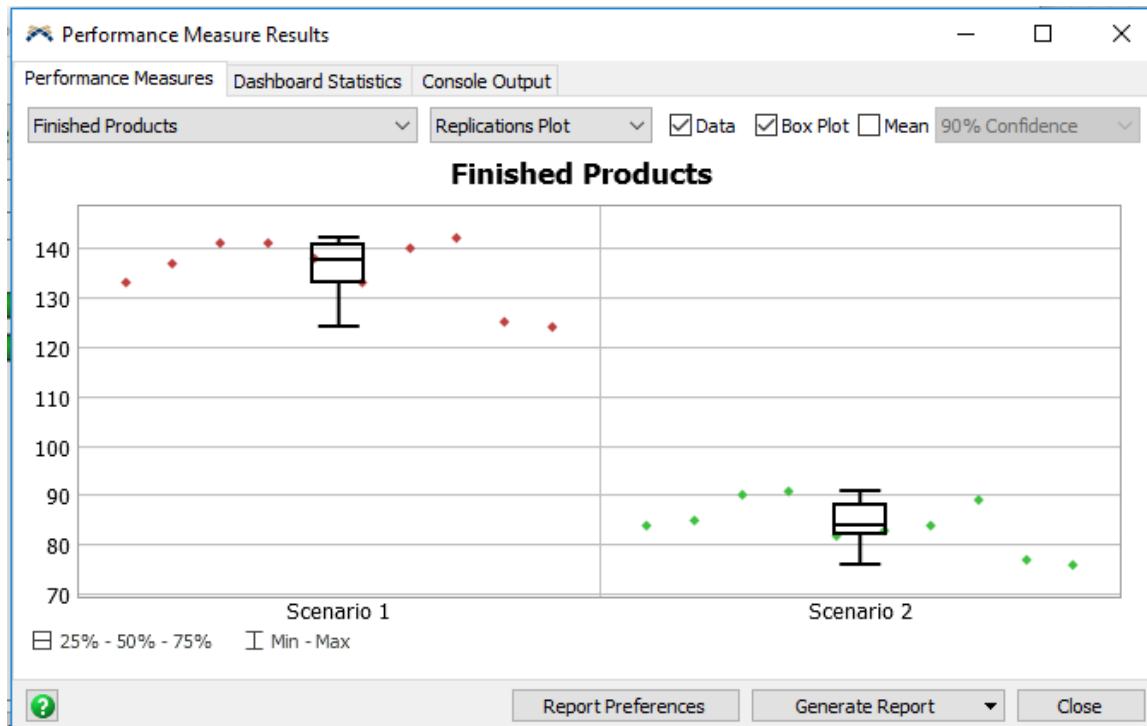
- In the Experimenter create a "Model Layout" variable and define the Scenarios as follows.
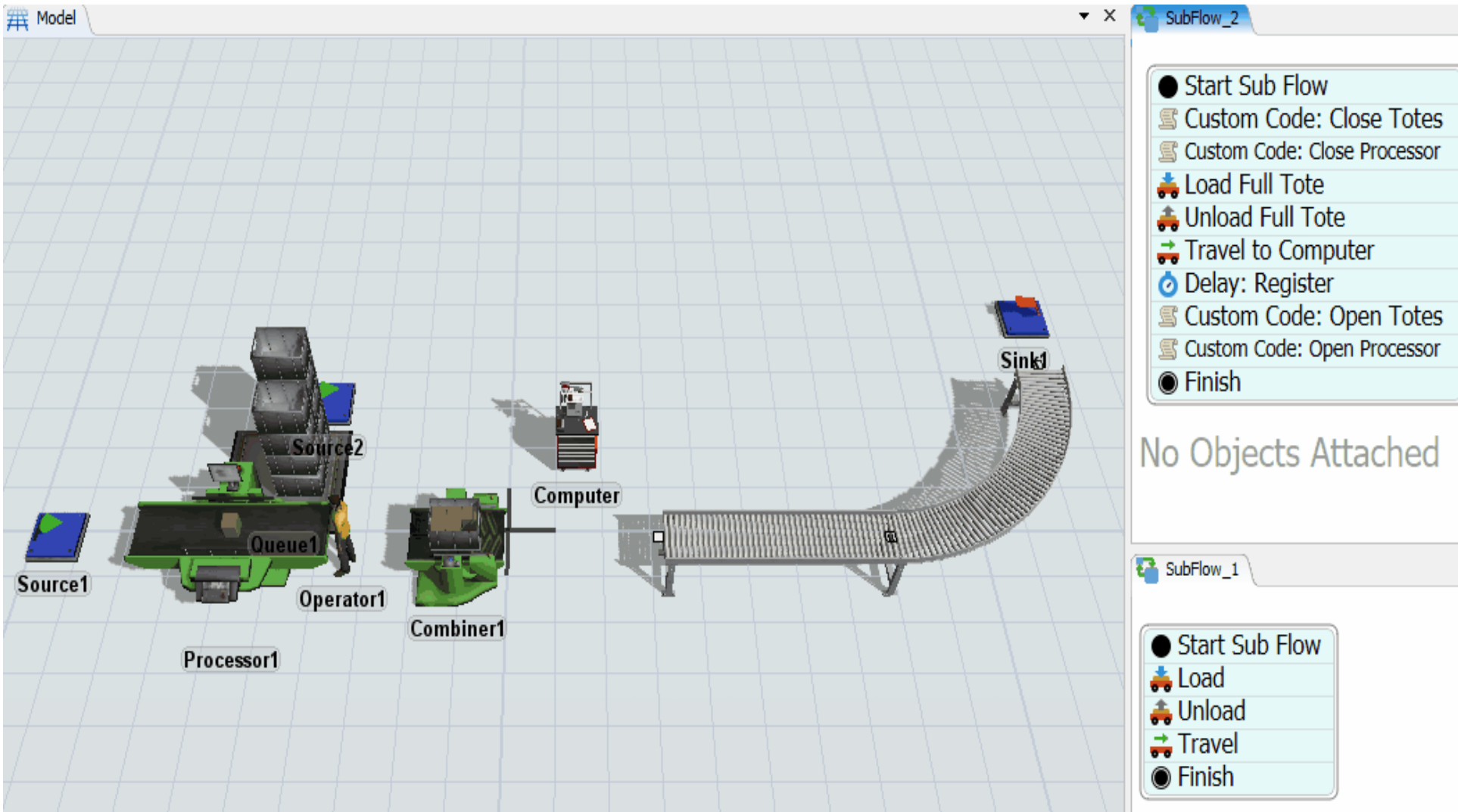
Tutorial 6

- Reset and Run again the Experiment and explore the results.
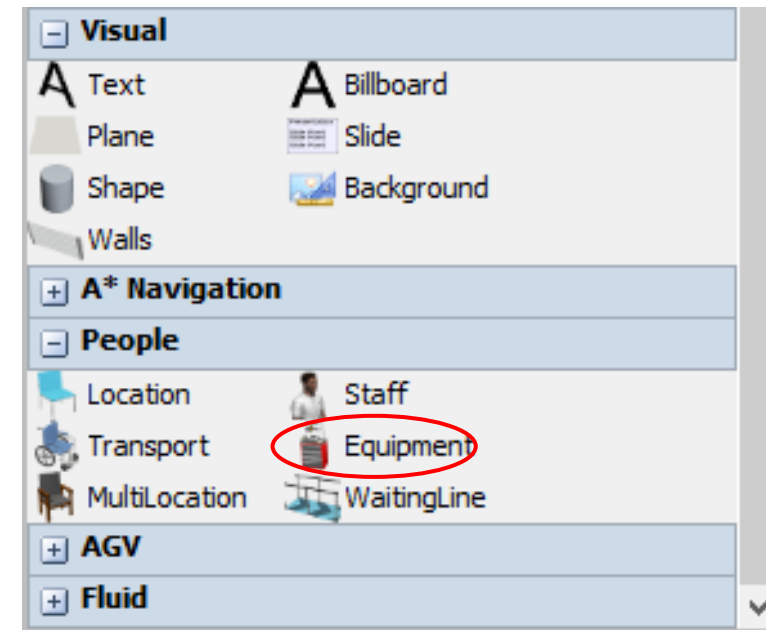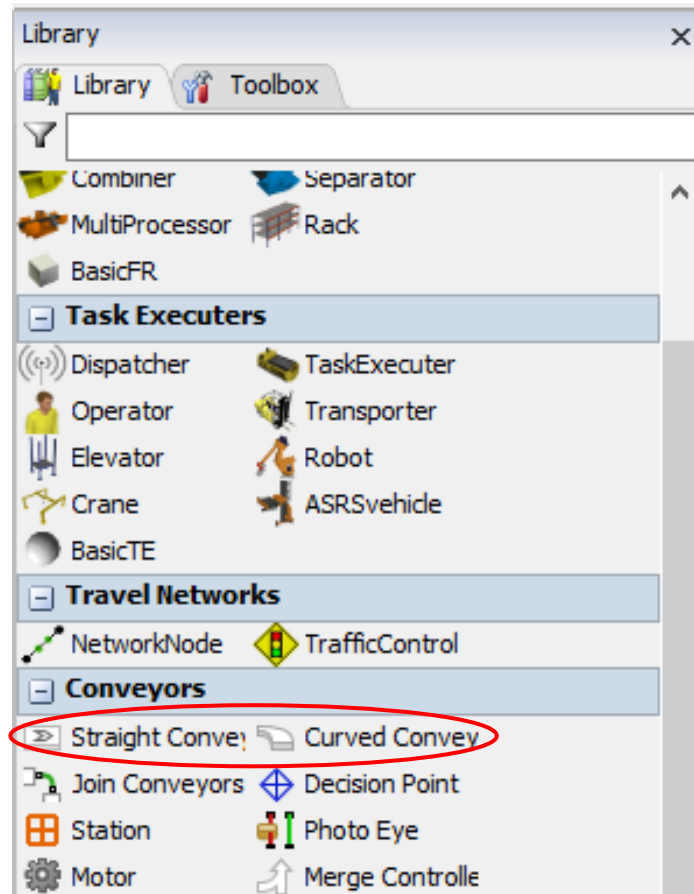
Tutorial 7 – Advanced Topics

Important Concepts:

- Combiner
- Conveyor
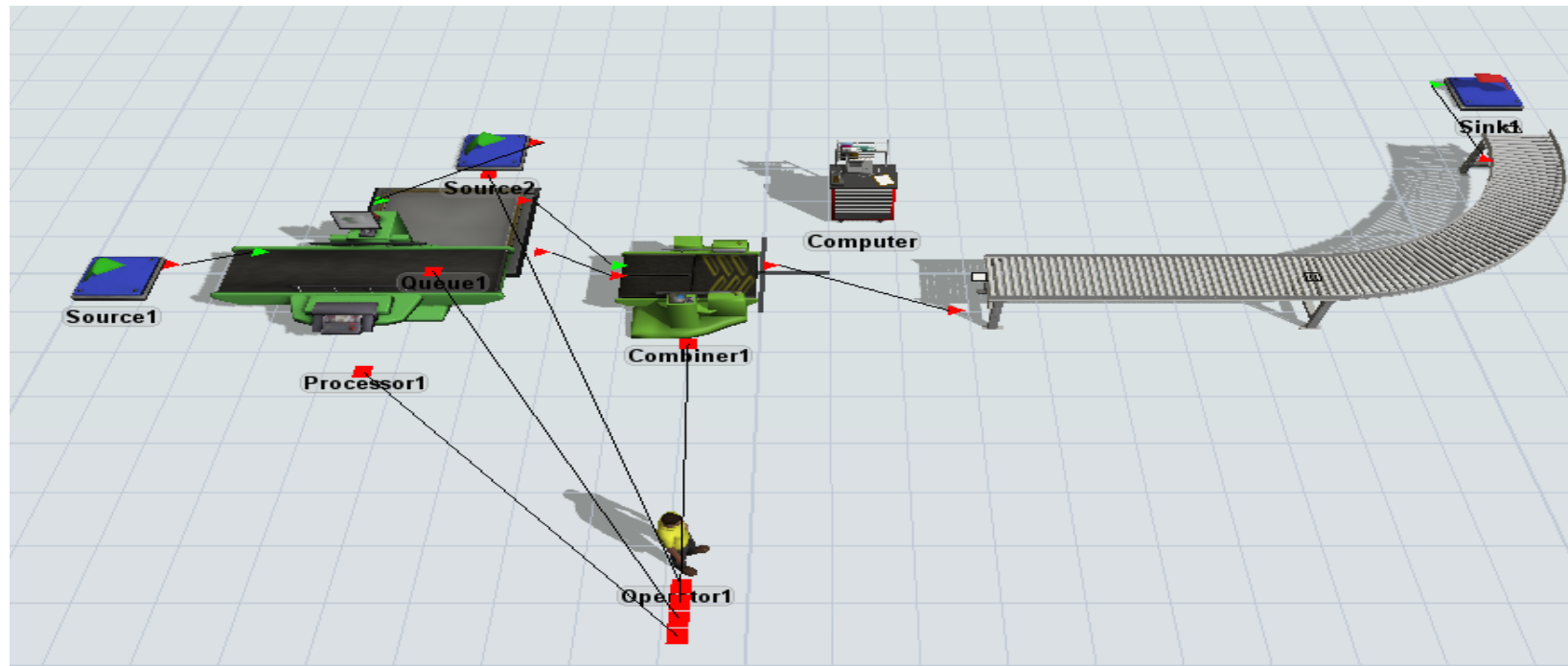- Sub Process Flows – Operator Sequence
- Items properties

Tutorial 7

- From the Library, drag and drop 2 Sources, 1 Sink, 1 Processor, 1 Queue, 1 Equipment, 1 Straight Conveyor, and 1 Curved Conveyor.

- Place and name the objects as presented in following image. Make Connections type "A" between the Source1-Processor1-Combiner1-Straight Conveyor/Curved Conveyor-Sink, and between Source2-Queue1-Combiner1. *NOTE: make the connection between Queue1-Combiner1 before Processor1-Combiner1.*

- Make connections type "S" between Source 2 – Operator1, Queue1 – Operator1, Processor1 – Operator1, and Combiner 1 – Operator1.
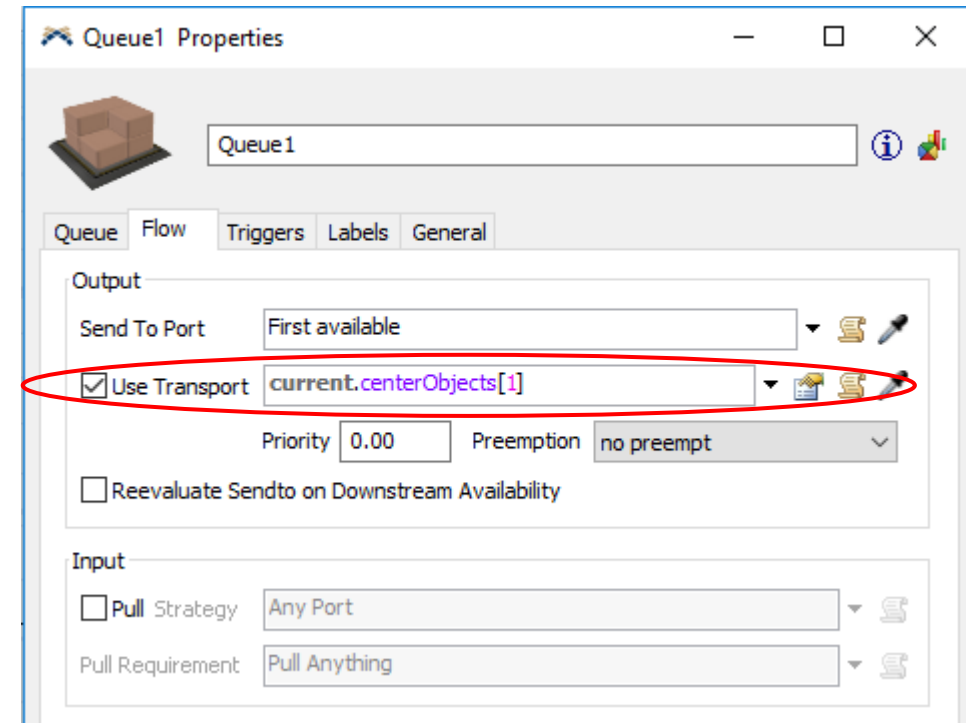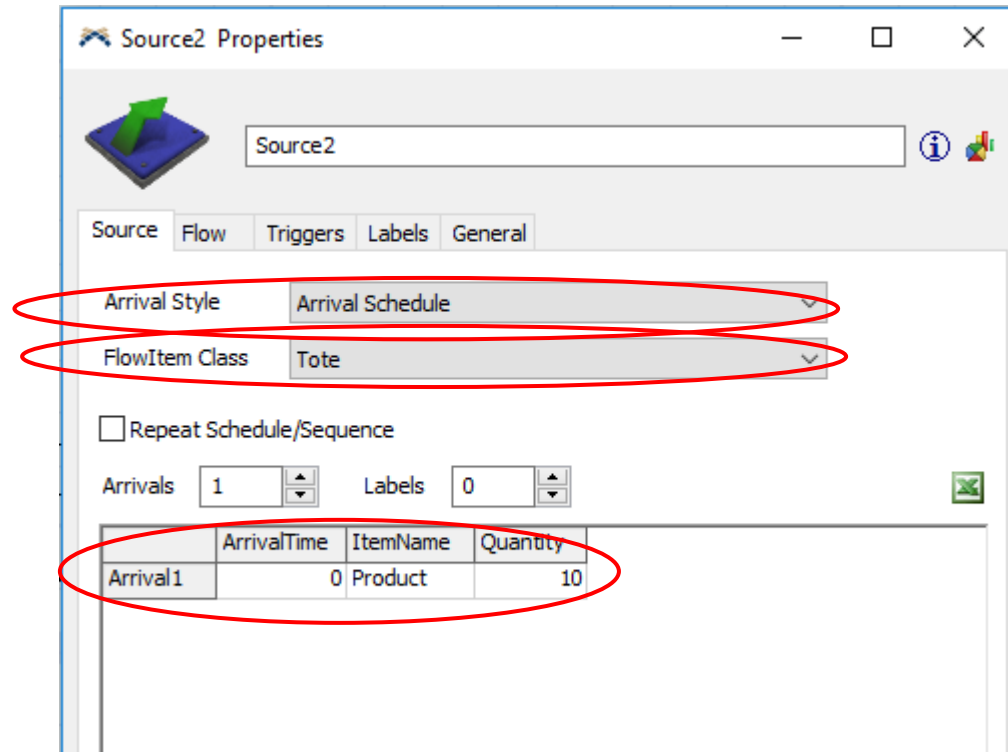
- Define Source1 Properties as shown bellow – leave the rest as default.
- In the FlowItem Class click on "Go to FlowItem Bin", select the box Item and change its dimensions as shown (i.e. 0.3, 0.3, 0.3)
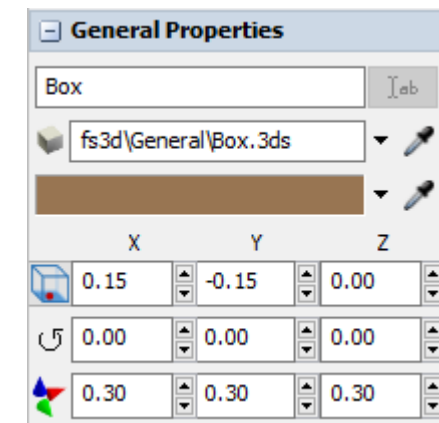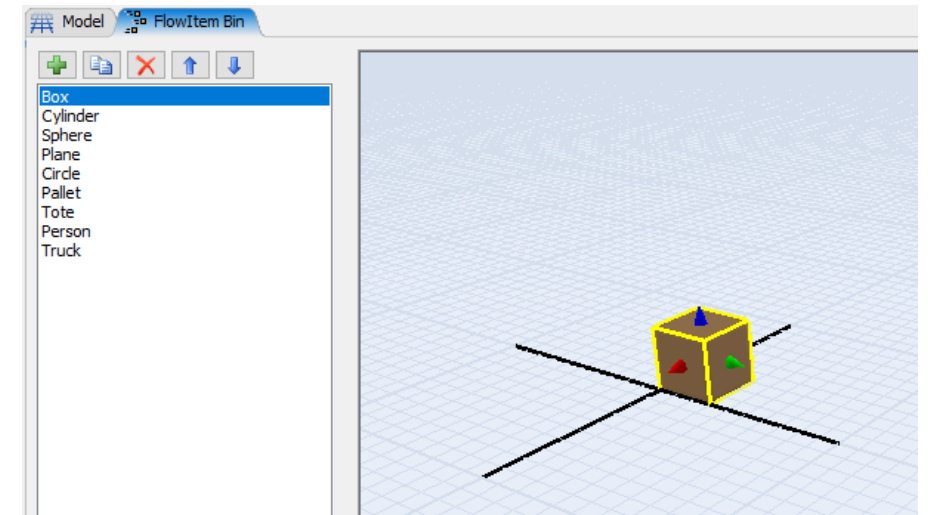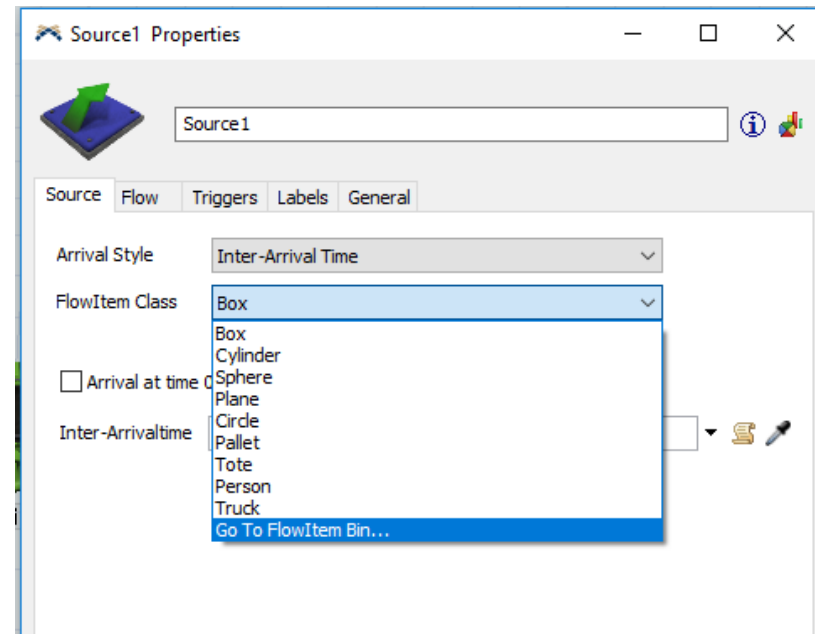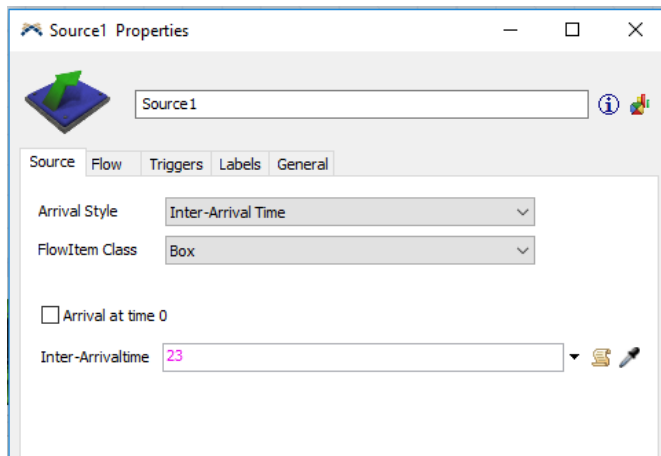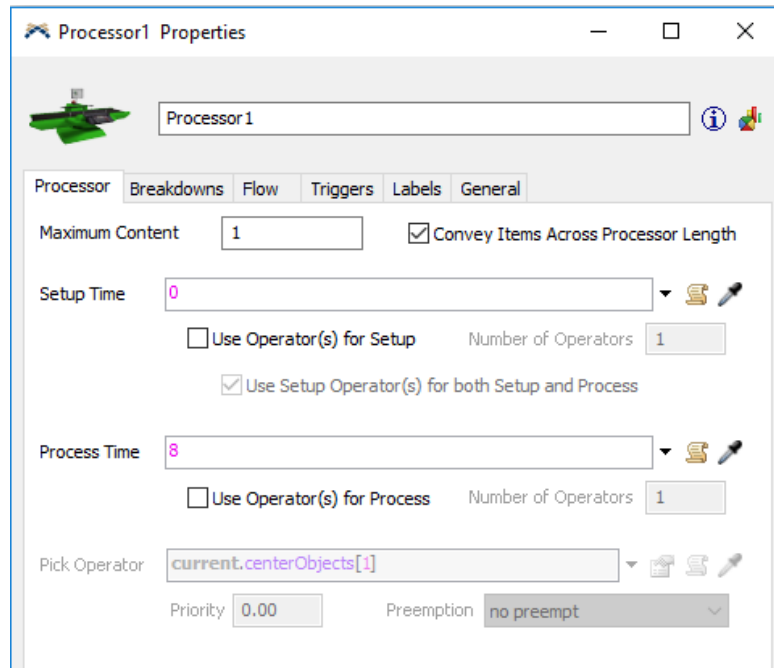
Tutorial 7

- Define Source2 Arrival Style as shown bellow – leave the rest as default.

- Define Queue1 Properties as shown bellow, i.e. Use Transport – Leave the rest as default.

Tutorial 7

- Define Processor1 properties as shown bellow – leave the rest as default.
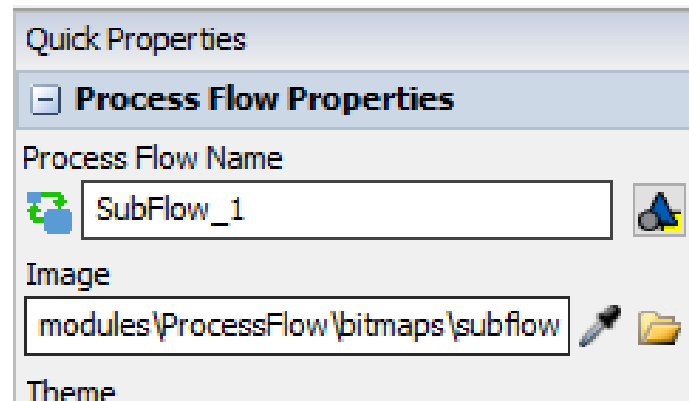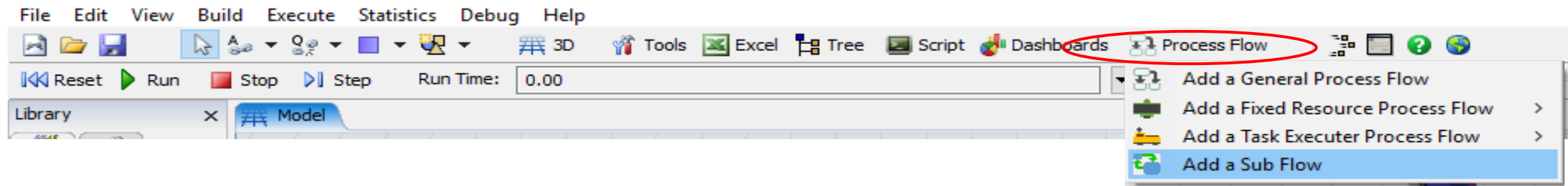- Define Combiner 1 properties as shown bellow – leave the rest as default.

Tutorial 7

- At the General Properties, modify the Combiner 1 visual appearance as shown bellow.
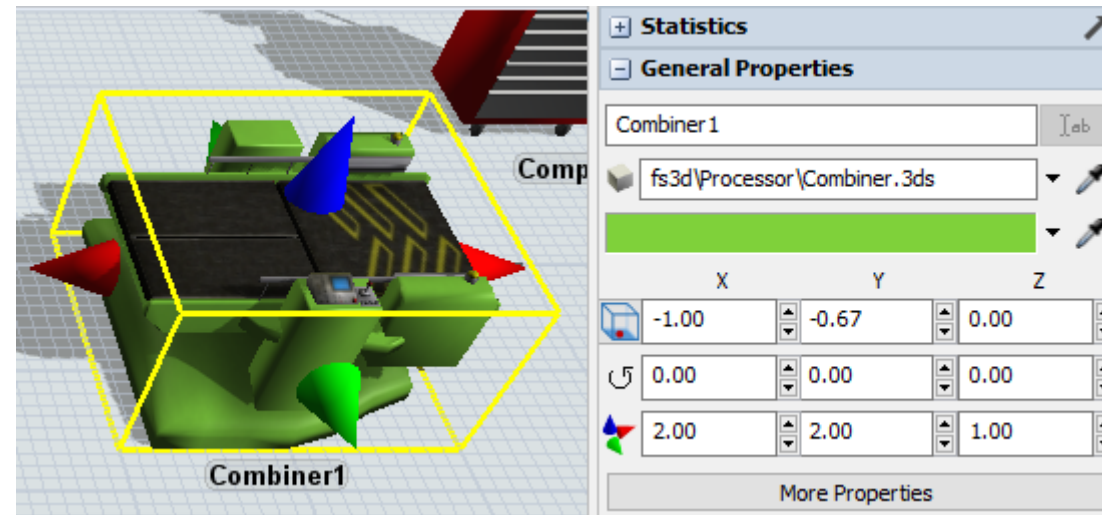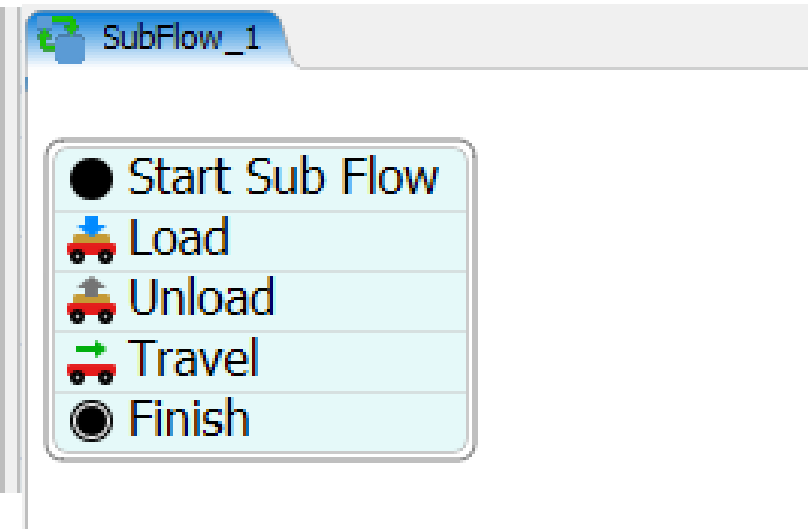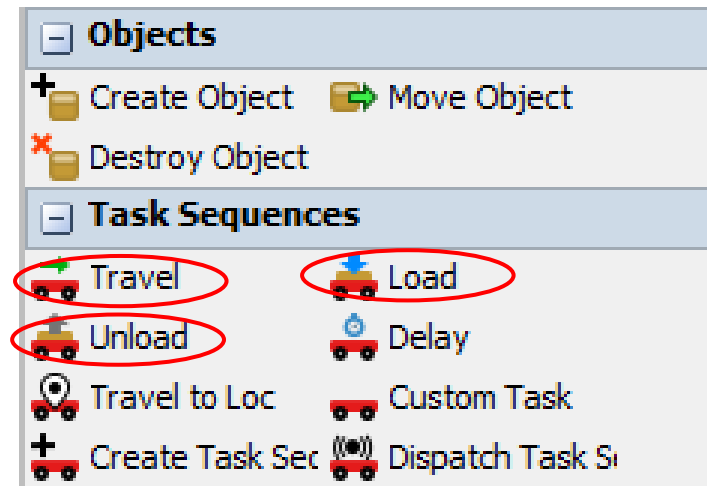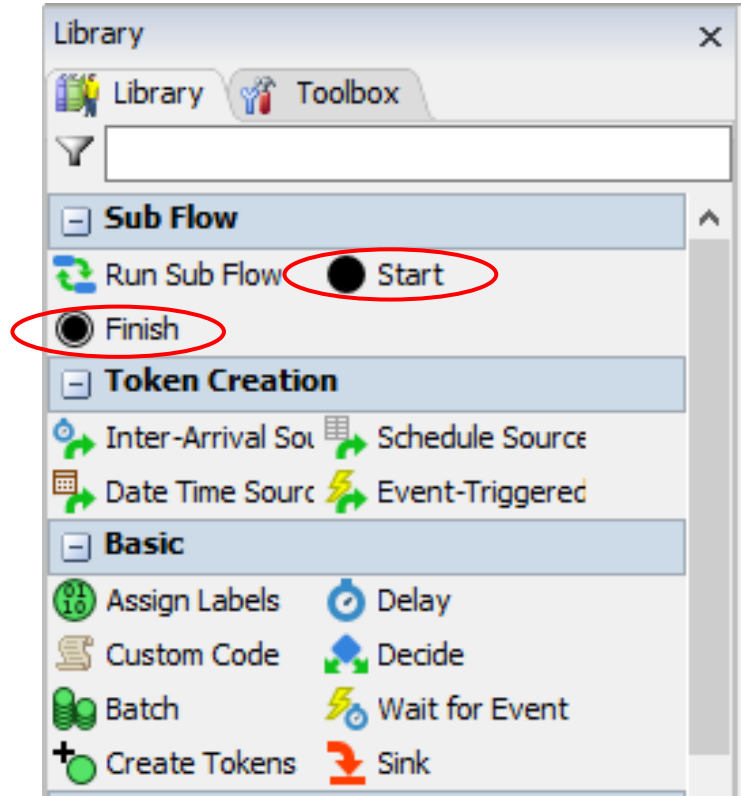
Tutorial 7

- At the main toolbar select the Process Flow and then "Add a Sub Flow".

- At the Quick Properties change its name to "SubFlow_1".

- While being in the Process Flow window, at the Library drag and drop 1 Start, 1 Finish, 1 Load, 1 Unload, and 1 Travel. Place them all within the same group as shown bellow and change the "Start" name accordingly.
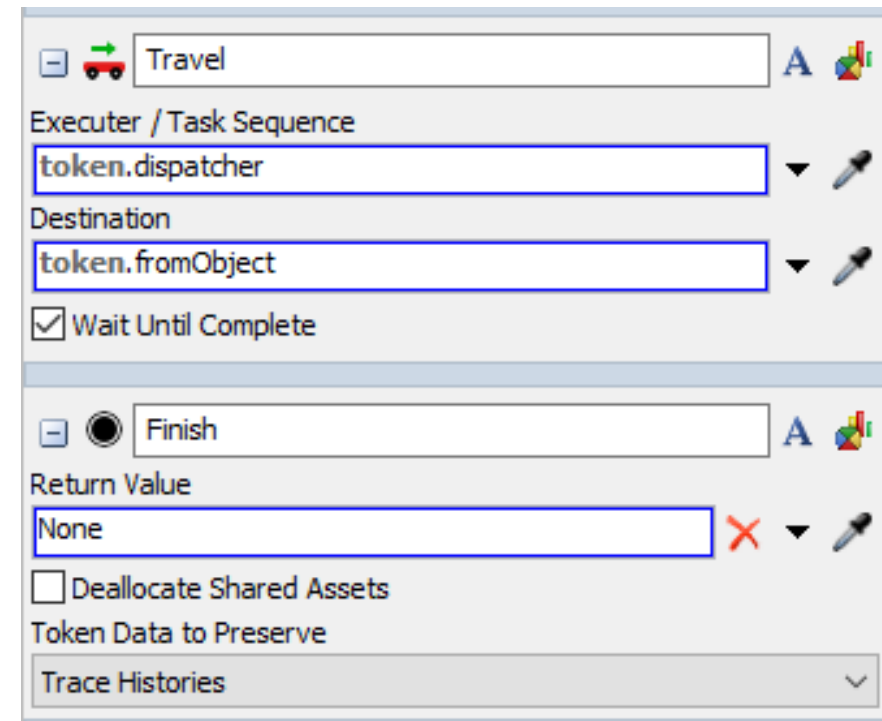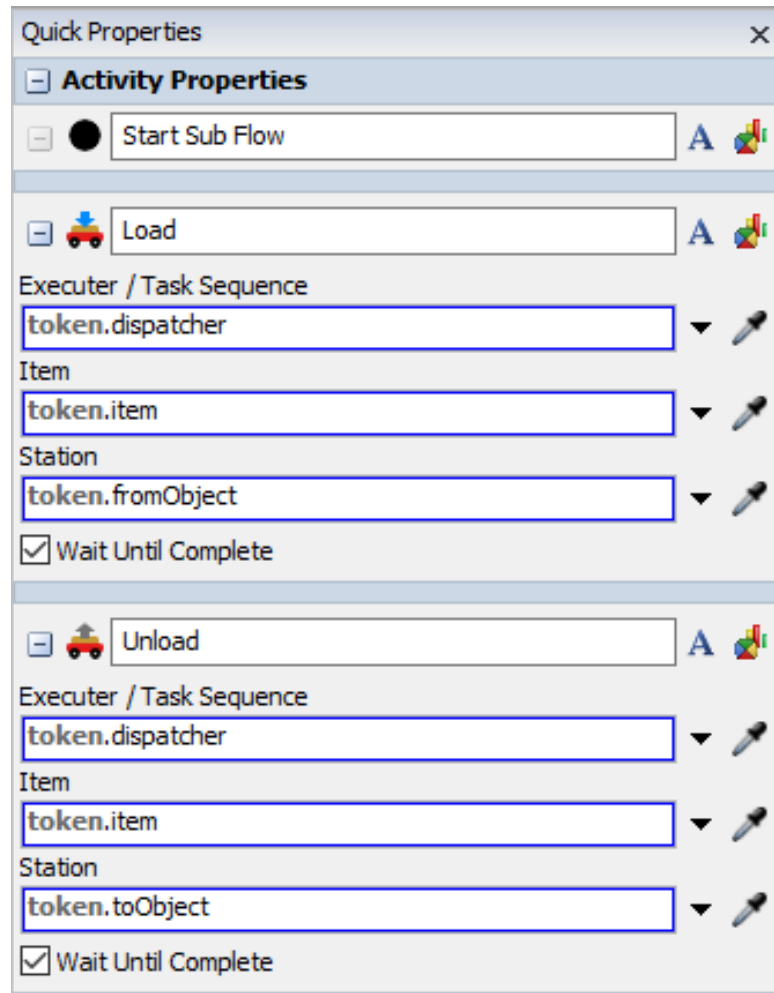
Tutorial 7

- In the Processor1 "Flow" properties, select the "Use Transport" button and the select the "ProcessFlow: Use Task Sequence Sub Flow" option and change the properties.
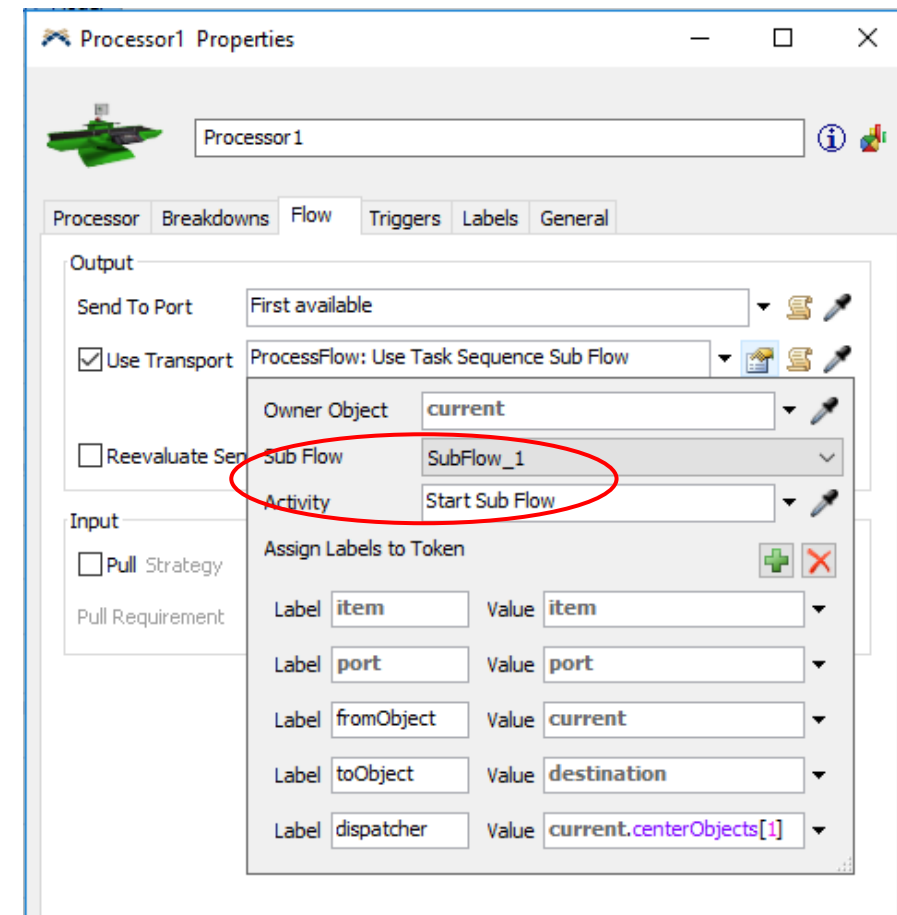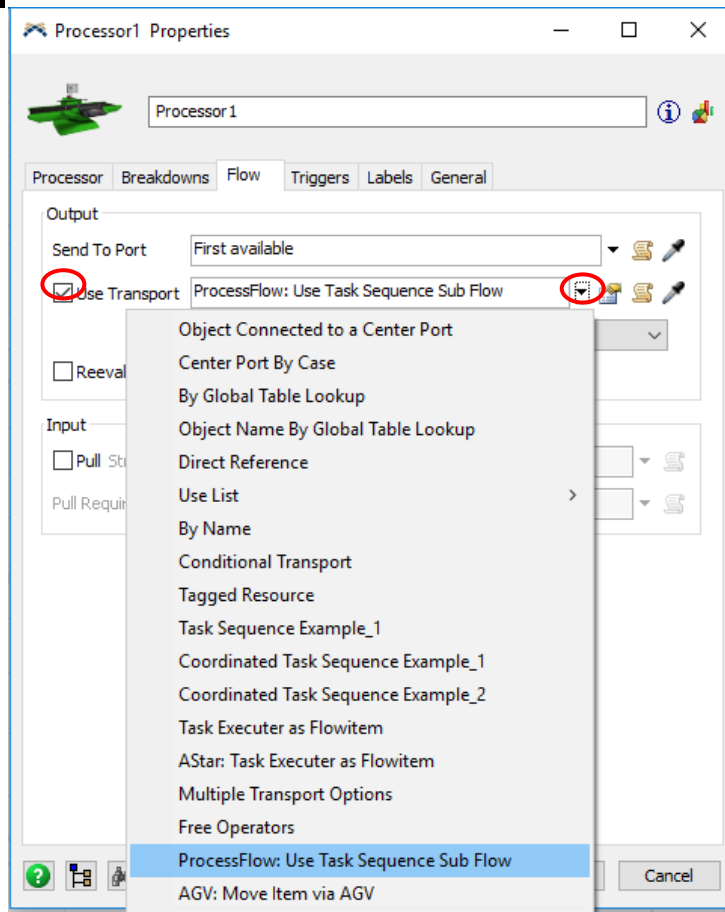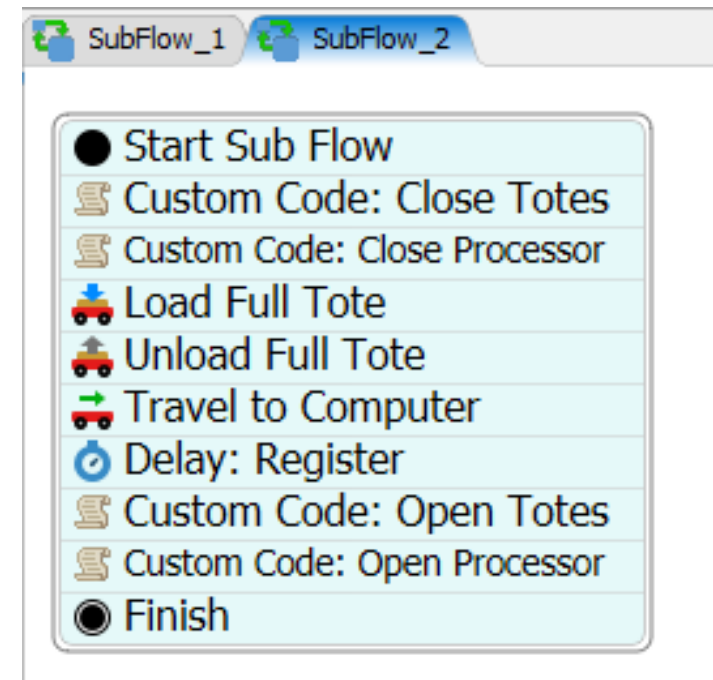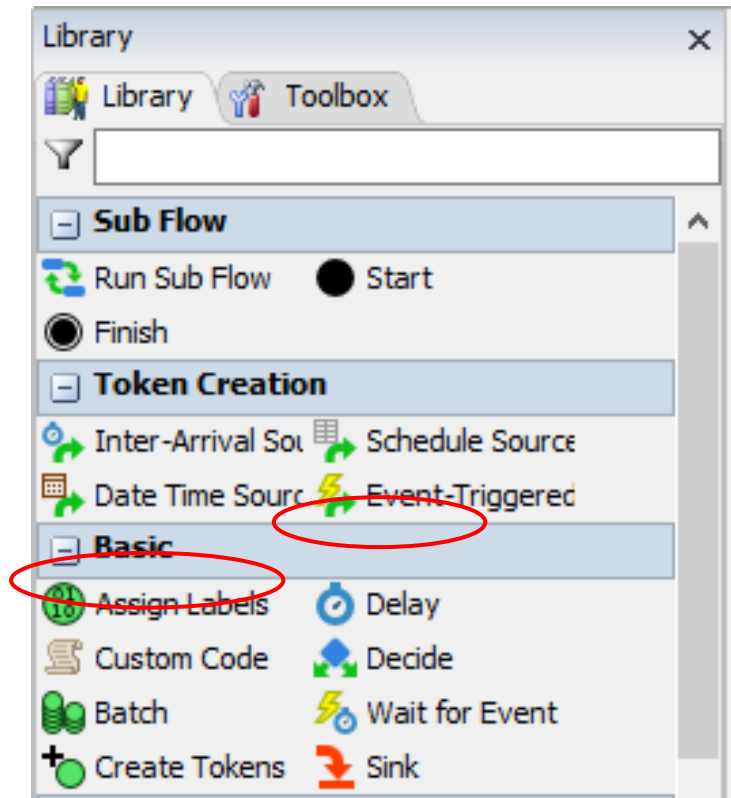
- In the SubFlow_1 window, select the group and change their Quick Properties as follows.
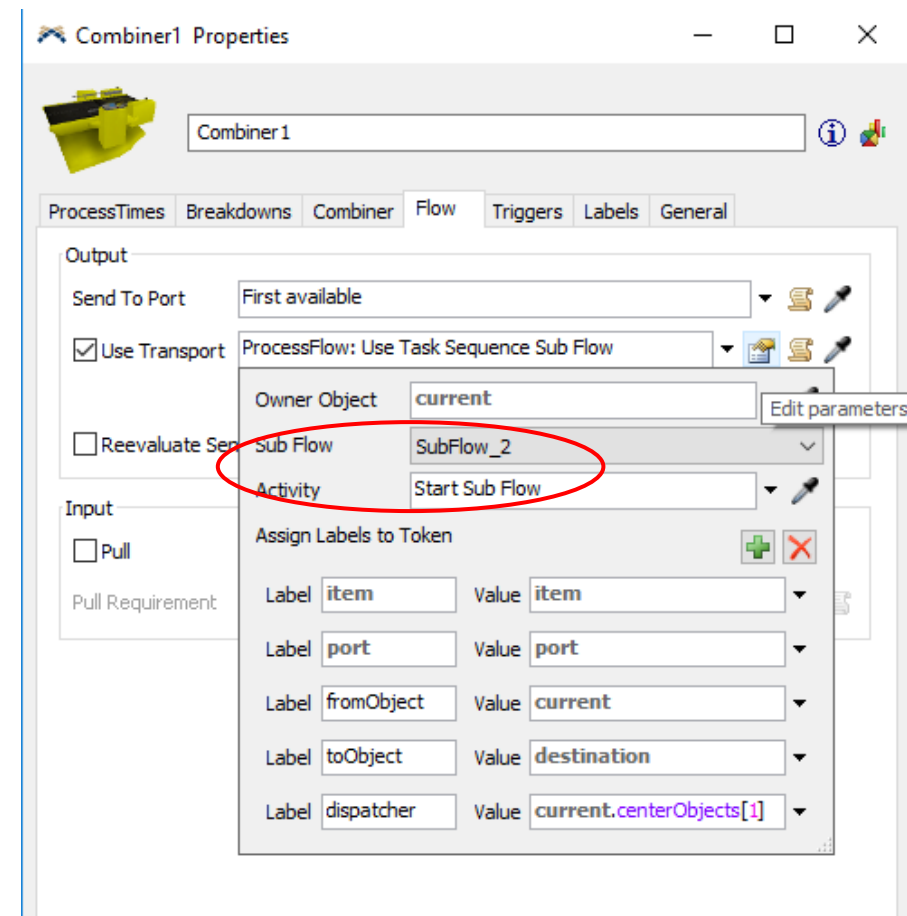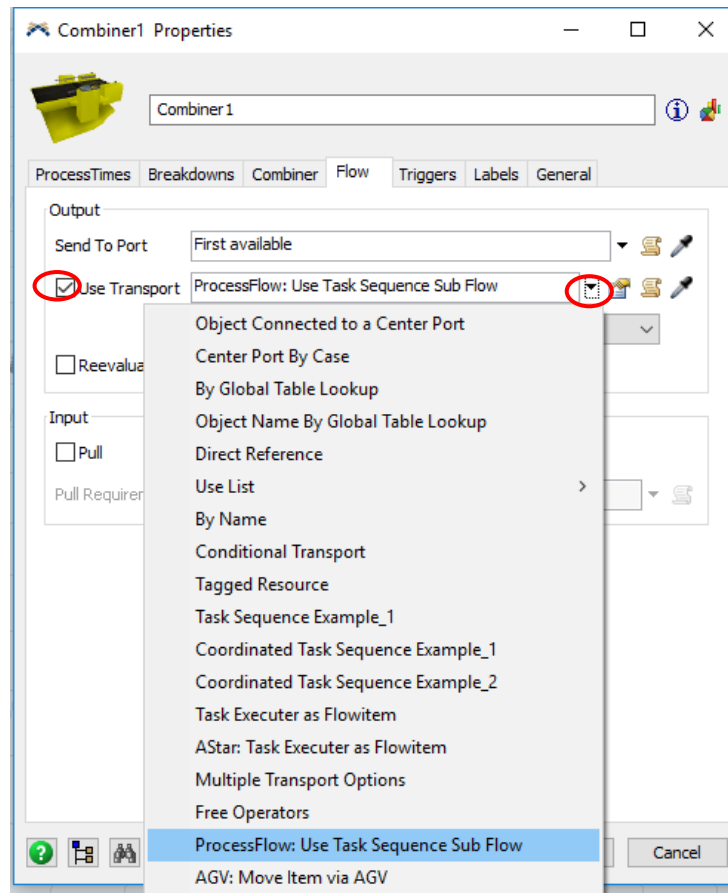
Tutorial 7

- Create a new Sub Flow as explained before and name it SubFlow_2.

- At the Library drag and drop the following activities - Place them all within the same group as shown bellow and change the names accordingly.
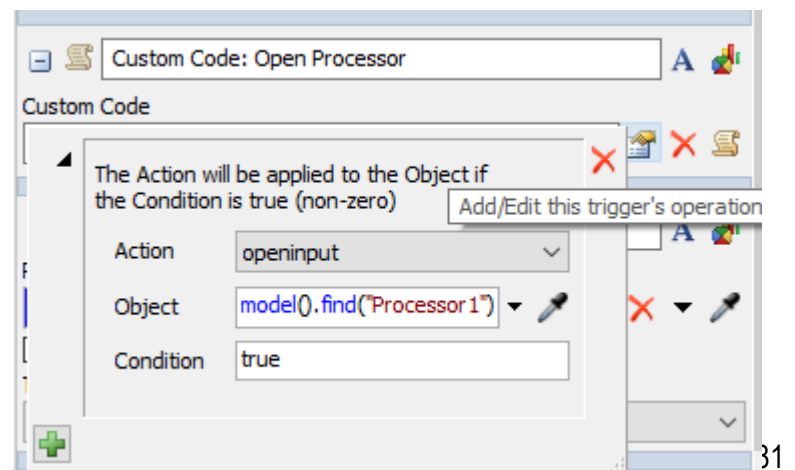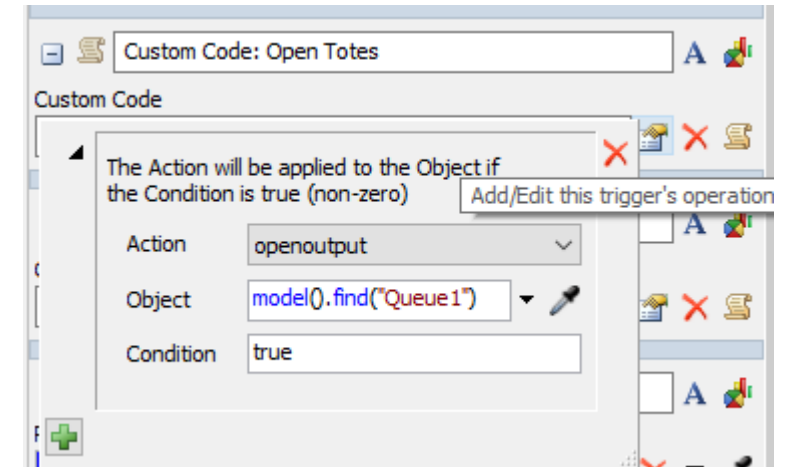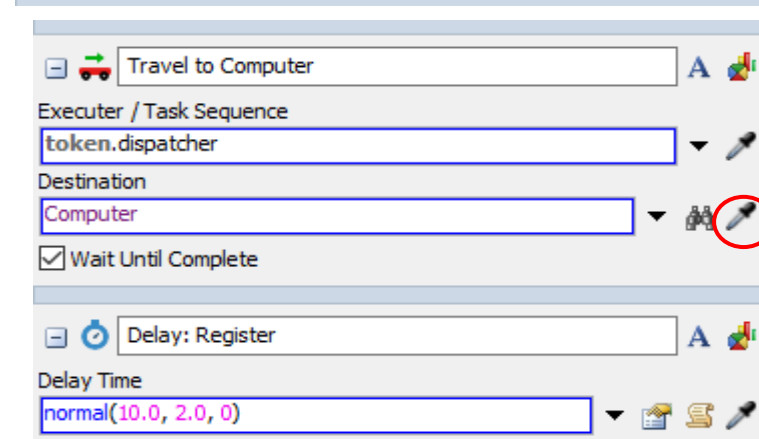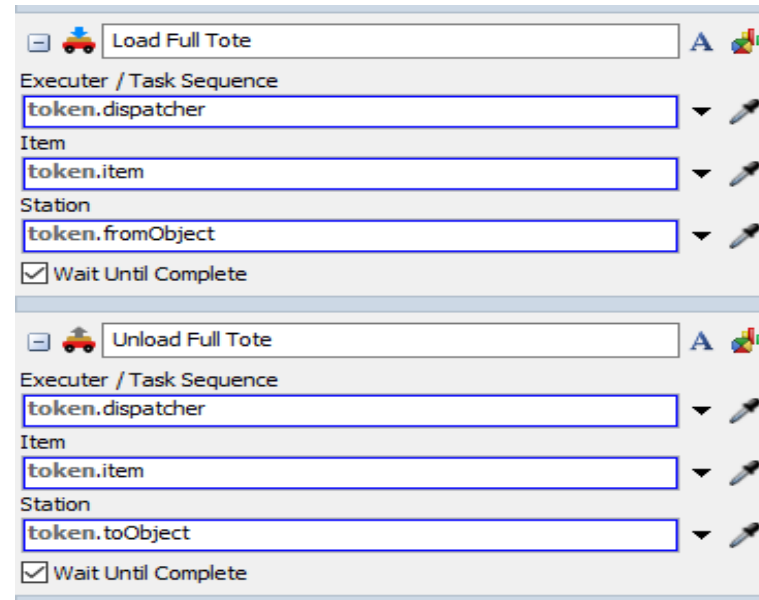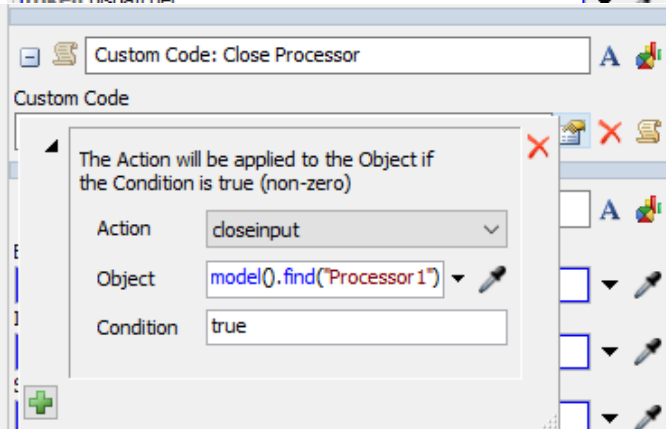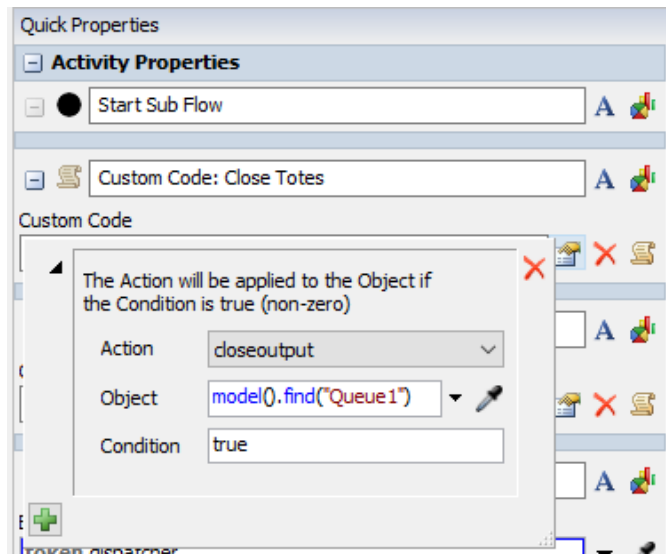
Tutorial 7

- In the Combiner1 "Flow" properties, select the "Use Transport" button and the select the "ProcessFlow: Use Task Sequence Sub Flow" option and change the properties.

- In the SubFlow_2 window, select the group and change their Quick Properties as follows.

Tutorial 7

- Run the model to check for errors.