INTRODUCTION to SIMIO

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Chapter 1: Getting Started

Overview

The Simio modeling software lets you build and run dynamic 3D animated models of a wide range of systems – e.g. factories, supply chains, emergency departments, airports, and service systems. Simio employs an object approach to modeling, whereby models are built by combining objects that represent the physical components of the systems.

An object has its own custom behavior as defined by its internal model that responds to events in the system. For example a production line model is built by placing objects that represent machines, conveyors, forklift trucks, aisles, etc. You can build your models using the objects provided in the Standard Object Library, which is general purpose set of objects that comes standard with Simio. You can also build your own libraries of objects that are customized for specific application areas. As you see shortly you can also modify and extend the Standard Library object behavior using process logic.

In Simio object definitions and models are the same thing. Whenever you build a model you have defined the logic for an object that can be used in other models. An object (or model) is defined by its properties, states, events, external view, and logic. These are key Simio concepts to understand for building and using objects.

Properties are input values that can be specified by the user of the object. For example an object representing a server might have a property that specifies the service time. When the user places the server object into their facility model they would also specify this property value.

An object's states are dynamic values that may change as the model executes. For example the busy and idle status of a server object could be maintained by a state variable named Status that is changed by the object each time it starts or ends service on a customer.

Events are things that the object may "fire" at selected times. For example a server object might have an event fire each time the server completes processing of a customer, or a tank object might fire an event whenever it reaches full or empty. Events are useful for informing other objects that something important has happened.

The external view of an object is the 3D graphical representation of the object. This is what a user of the object will see when it is placed in their facility model.

The object's logic is an internal model that defines how the object responds to specific events that may occur. For example a server object may have a model that specifies what actions take place when a customer arrives to the server. The internal model gives the object its unique behavior.

One of the powerful features of Simio is that whenever you build a model of a system, you can turn that model into an object definition by simply adding some input properties and an external view. Your model can then be placed as a sub-model within a higher-level model. Hence hierarchical modeling is very natural in Simio.

Models and Projects

When you first open Simio you see a Start Page which includes links to the Simio Reference Guide, training videos, example models, and SimBits. The SimBits are small models that illustrate how to approach common modeling situations. From the Start Page you can click on New Model in the ribbon, or the Create New Model link to open a new model.

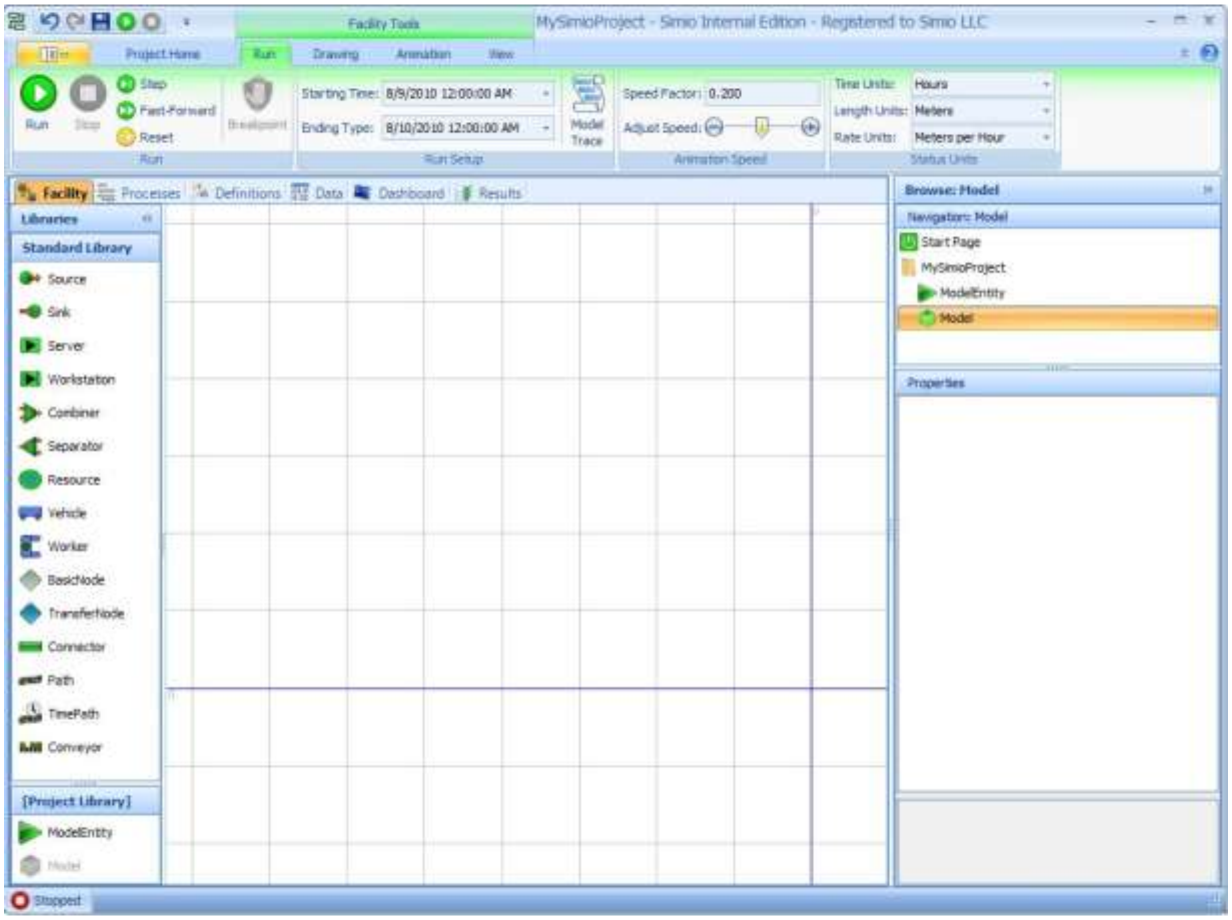
Models are defined within a project. A project may contain any number of models and associated experiments (discussed later). A project will typically contain a main model and an entity model. When you open up a new project, Simio automatically adds the main model (default name Model) and entity model (default name ModelEntity) to the project. You can rename the project and these models by right clicking on them in the project navigation tree. You can also add additional models to the project by right clicking on the project name. This is typically done to create sub-models that are then used in building the main model.

The entity model is used to define the behavior of the entities that move through the system. In older simulation systems entities cannot have behavior, and therefore there is no mechanism for building an entity model. However in Simio entities can have behaviors that are defined by their own internal model. The default model entity is “dumb” in that it has no explicit behavior, however as you will see later you can modify the entity model to take specific actions in response to events. You can also have multiple types of entity models in your project, with each having its behavior. For example in a model of an emergency department you could have different entities representing patients, nurses, and doctors.

As we will see later a project can also be loaded into Simio as modeling library. Hence some projects contain a collection of models for a specific application, and other projects contain models that are primarily used as building blocks for other models. The same project can either be opened for editing or be loaded as library.

The Simio User Interface

The initial view of your Simio project is shown below. The key areas in this screen include the ribbons across the top (currently showing the Run ribbon), the tabbed panel views with the Facility highlighted just below the ribbons, the libraries on the left, the browse panel on the right, and the Facility window in the center.



The ribbons are tabbed UI panels that provide a convenient way quickly to access the many functions available to you for building, animating, and running models. You can manually switch between ribbons by clicking on the ribbon tabs. You can also condense the ribbons to just the tabs by double-clicking on any tab. In this mode clicking on the tab will expand the ribbon until you click in the model, and then the ribbon will then shrink back to just tabs. Double-clicking again on any ribbon tab will restore the ribbons to their regular size.

The Browse panel on the right provides for project navigation and property editing. The upper navigation window is used to switch between the Start Page, Project view, and the associated models and experiments. You can switch between models by simply clicking on the model in the navigation tree. For example clicking on the main model will make this the active model and display the Facility window for that model. Likewise clicking on the ModelEntity will make the default entity the active model, and display the initially empty set of processes that defines entities' behavior. The properties window that is located in the Browse panel immediately below the navigation window is used for editing the properties of objects. We will discuss this window in more detail later. You can open and close the Browse panel by clicking on the << and >> in the title bar of the panel.

Whenever the Facility window of a model is selected the Libraries panel on the left displays the libraries that are open and available for modeling within the facility. The libraries will include the Standard

Library, the Project Library, and any additional projects that have been loaded as libraries from the Project Home ribbon. The Standard Library is a general purpose library of objects that is provided with Simio for modeling a wide range of systems. The Project Library is a library of objects corresponding to the current models in your project. This lets you use your project models as sub-models that can be placed multiple times within a model. Note that the active model is grayed out in the Project Library since a model cannot be placed inside itself.

The Facility window that is shown in the center is drawing space for building your object-based model. This panel is shown whenever the Facility tab is selected for a model. This space is used to create both the object-based logic and the animation for the model in a single step. The other panel views associated with a model include Process, Definition, Data, Dashboard, and Results. The Process panel is used for defining custom process logic for your models. The ability to mix object-based and process modeling within the same model is one of the unique and very powerful features of Simio – this combines the rapid modeling capabilities of objects with the modeling flexibility of processes. The Definitions panel is used to define different aspects of the model, such as its external view and the properties, states, and events that are associated with the model. The Data panel is used to define data that may be used by the model, and imported/exported to external data sources. The Dashboard panel provides a 2D drawing space for placing buttons, dials, plots, etc., for real time viewing and interactions with the model. The Results panel displays the output from the model in the form of both a pivot grid as well as traditional reports. Note that you can view multiple model windows at the same time by dragging a window tab and dropping it on one of the layout targets. For now we will be focusing on the Facility window and will defer further discussion of these additional model windows until later.

Objects and Libraries

The objects within a library are one of five basic types:

- **Fixed**: Has a single fixed location in the system such as a machine.
- **Link**: Provides a pathway over which entities may move.
- **Node**: Defines an intersection between one or more incoming/outgoing links. Nodes can also be associated with fixed objects to provide entry and exit points for the object.
- **Entity**: Defines a dynamic object that can be created and destroyed, move over a network of links and nodes, and enter/exit fixed objects through their associated nodes.
- **Transporter**: Defines a special type of entity that can also pickup and drop off other entities at nodes.

Note that these types define the general behavior, but not the specific behavior of the object. The specific behavior an object is defined by the internal model for that object. For example we could have a library of a half a dozen different types of transporters, each with their own specific behaviors as defined by their models. However they would all share the common ability to move across a network of links and nodes, and pickup and drop off entities at nodes along the way.

A library may contain objects of any these five types. The Standard Library includes objects of all types except for the entity type, since the entity is typically defined within the Project Library.

The Standard Library contains the following objects:

Object	Description
Source	Generates entity objects of a specified type and arrival pattern.
Sink	Destroys entities that have completed processing in the model.
Server	Represents a capacitated process such as a machine or service operation.
Workstation	Models a complex workstation with setup, processing, and teardown phases and secondary resource and material requirements.
Combiner	Combines multiple member entities together with a parent entity (e.g. a pallet).
Separator	Splits a batched group of entities or makes copies of a single entity.
Resource	A generic object that can be seized and released by other objects.
Vehicle	A transporter that can follow a fixed route or perform on demand transport pickups/drop offs. Additionally, an 'On Demand' routing type vehicle may be used as a moveable resource that is seized and released for non-transport tasks.
Worker	A moveable resource that may be seized and released for tasks as well as used to transport entities between node locations.
BasicNode	Models a simple intersection between multiple links.
TransferNode	Models a complex intersection for changing destination and travel mode.
Connector	A simple zero-time travel link between two nodes.
Path	A link over which entities may independently move at their own speeds.
TimePath	A link that has a specified travel time for all entities.
Conveyor	A link that models both accumulating and non-accumulating conveyor devices.

Note that the Standard Library is simply a project in Simio that contains a collection of models that have been given external views and associated properties that control their behavior.

Instantiating Objects in your Facility Model

The object libraries provide definitions for objects that can be placed into the facility model. There are several different ways to select and place objects into the facility model. For all objects except for links you can use any of the following methods:

1. Click on the object definition in the library (e.g. Source, Server, or Sink), and then click at the location in the Facility window where you would like to place the object.
2. Drag the object from the library to a location in the Facility window.
3. Double-click on the object definition in the library, click in each location in the Facility window where you would like to place the object, and then terminate multi-place mode by right clicking anywhere in the model.

Once you have placed an object in the facility you can move it by clicking on it and dragging it. You can change the default name by double-clicking on the name or by right-clicking on the object. You can resize objects (except for nodes) by dragging the resize handles that appear once the object has been selected.

In most cases placing an object will instantiate associated nodes as well as the main object. For example if you place a Server object named Server1 in your facility you are actually placing three separate but related objects. The main (center) object is the server itself and has a set properties related to the service operation. The small diamond object on the left is the associated input node named *Input@Server1* (a BasicNode) and you can move it independently of the server, and it also has its own set of properties which you may edit. The small diagonal object on the right is the output node named *Output@Server1* (a TransferNode) and you can select and move it independently and also edit its properties. If you move the main Server object it will also automatically drag with it the associated input and output node objects.

Links are special because they provide a pathway between two nodes, and hence must always start and end at a node. Links are not “placed” but are instead drawn as a polyline between two nodes. You can use either of the following methods to draw links.

1. Click on a link object in the library (e.g. Connector, Path, TimePath, Conveyor), and then click on the starting node for the link pathway, click at each intermediate vertex that you would like to add, and then click on the ending node for the pathway. You can abort link drawing by right-clicking before completing the link.
2. Double-click on a link object in the library, add a link instance as described above, and then repeat multiple times. Terminate multi-link draw mode by right clicking anywhere in the model.

Once you have drawn a link you can move any of its vertices by clicking and dragging the vertex.

Manipulating Facility Views

By default Simio provides a top-down 2-D view of the facility model. This is often a very convenient view for creating and editing your model. However facility models in Simio are defined in 3D. You can switch between the 2D and 3D views of the facility using the View section of the View ribbon, or by using the 2 and 3 keys on the keyboard. The View section also lets you set the facility model to auto-rotate in 3D – click anywhere in the facility to stop auto-rotation. You can also change the background color of the 3D space. Click anywhere in the facility and drag to pan the view. Press the right mouse button and move left and right to rotate the view, or up and down to zoom in and out. You can also zoom using the mouse wheel.

The visibility section of the View ribbon lets you selectively hide/show different aspects of the facility model – e.g. you can hide all nodes and links.

You can use the Named Views section of the View ribbon to create and switch to named views into the facility model – such as the assembly area or shipping. This is a useful feature for navigating through very large models.

Editing Object Properties

Whenever you select an object in the facility (by clicking on it) the properties of the selected object are displayed for editing in the Property window in the Browse panel on the right. For example, if you select a Server object in the facility the properties for the Server will be displayed in the Property window. The properties are organized into categories that can be expanded and collapsed. In the case of the Server in the Standard Library the Process Logic category is initially expanded, and all others are initially collapsed. Clicking on +/- will expand and collapse a category. Whenever you select a property in the property grid a description of the property appears at the bottom of the grid.

The properties for an object are defined by the designer of that object. The properties may be different types such as strings, numbers, selections from a list, and expressions. For example the Ranking Rule for the Server is selected from a drop down list and the Processing Time is specified as an expression.

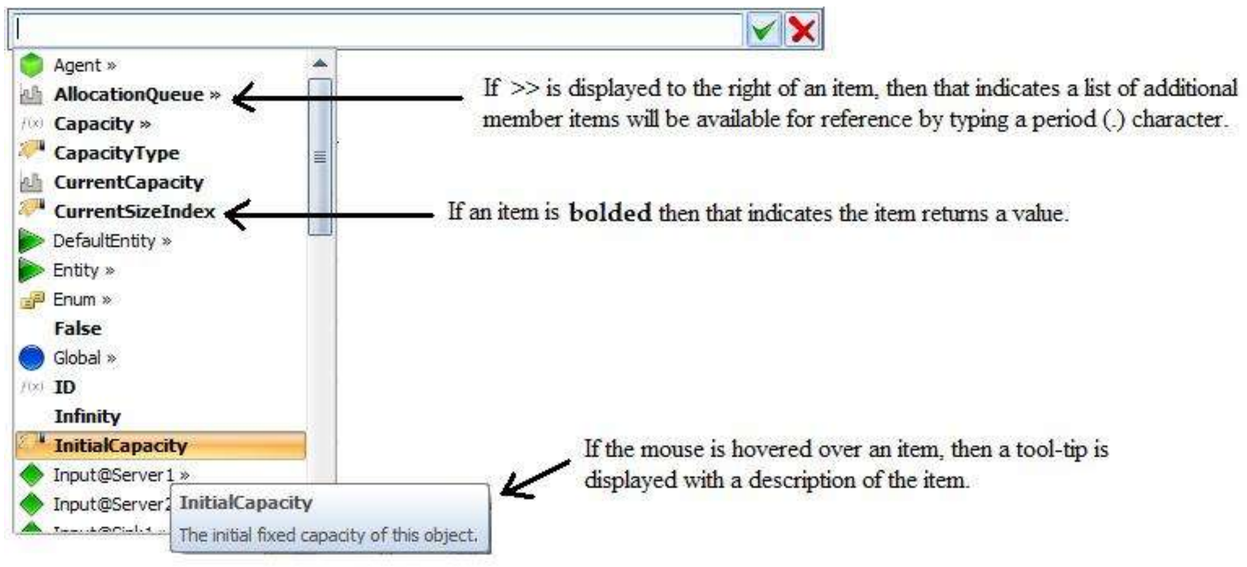
For expression fields (e.g. Processing Time) Simio provides an expression builder to simplify the process of entering complex expressions. When you click in an expression field a small button with a down arrow appears on the right. Clicking on this button opens the expression builder. The expression builder is very similar to IntelliSense® in the Microsoft family of products and tries to find matching names or keywords as you type. You can use math operators +, –, *, /, and ^ to form expressions. You can use parenthesis as needed to control the order of calculation (e.g. *2*(3+4)^(4/2)*). Logical expressions can be expressed using <, <=, >, >=, !=, or ==. Logical expressions return a number value of 1 when true, and 0 when false. For example *10*(A > 2)* returns a value of 10 if *A* is greater than 2. Arrays (up to 10 dimensions) are 1-based and are indexed with square brackets (e.g. *A[2,3,1]* indexes into the three dimensional state array named *A*). Model properties can be referenced by property name. For example if *Time1* and *Time2* are properties that you have added to you model then you can enter an expression such as *(Time1 + Time2)/2*.

A common use of the expression builder is to enter random distributions. These are specified in Simio in the format Random.DistributionName(Parameter1, Parameter2, …, ParameterN), where the number and meaning of the parameters are distribution dependent. For example Random.Uniform(2,4) will return a uniform random sample between 2 and 4. To enter this in the expression builder begin typing "Random". As you type the highlight in the drop list will jump to the word Random. Typing a period will then complete the word and display all possible distribution names. Typing a "U" will then jump to *Uniform(min, max)*. Pressing enter or tab will then add this to the expression. You can then type in the numeric values to replace the parameter names min and max. Note that highlighting a distribution name in the list will automatically bring up a description of that distribution.

Math functions such as Sin, Cos, Log, etc., are accessed in a similar way using the keyword Math. Begin typing "Math" and enter a period to complete the word and provide a list of all available math functions. Highlighting a math function in the list will automatically bring up a description of the function.

Object functions may also be referenced by function name. A function is a value that is internally maintained or computed by Simio and can be used in an expression but cannot be assigned by the user. For example all objects have function named *ID* that returns a unique integer for all active objects in the model. Note that in the case of dynamic entities the *ID* numbers are reused to avoid generating very large numbers for an ID.

Some other features of Simio's expression building interface are illustrated below:



If >> is displayed to the right of an item, then that indicates a list of additional member items will be available for reference by typing a period (.) character.

If an item is **bolded** then that indicates the item returns a value.

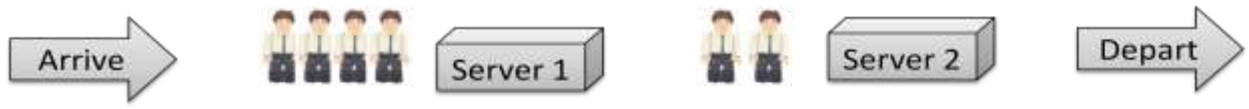
If the mouse is hovered over an item, then a tool-tip is displayed with a description of the item.

InitialCapacity
The initial fixed capacity of this object.

If you type an invalid entry into a property field the field turns a salmon color and the error window will automatically open at the bottom. If you double-click on the error in the error window it will then automatically take you to the property field where the errors exist. Once you correct the error the error window will automatically close.

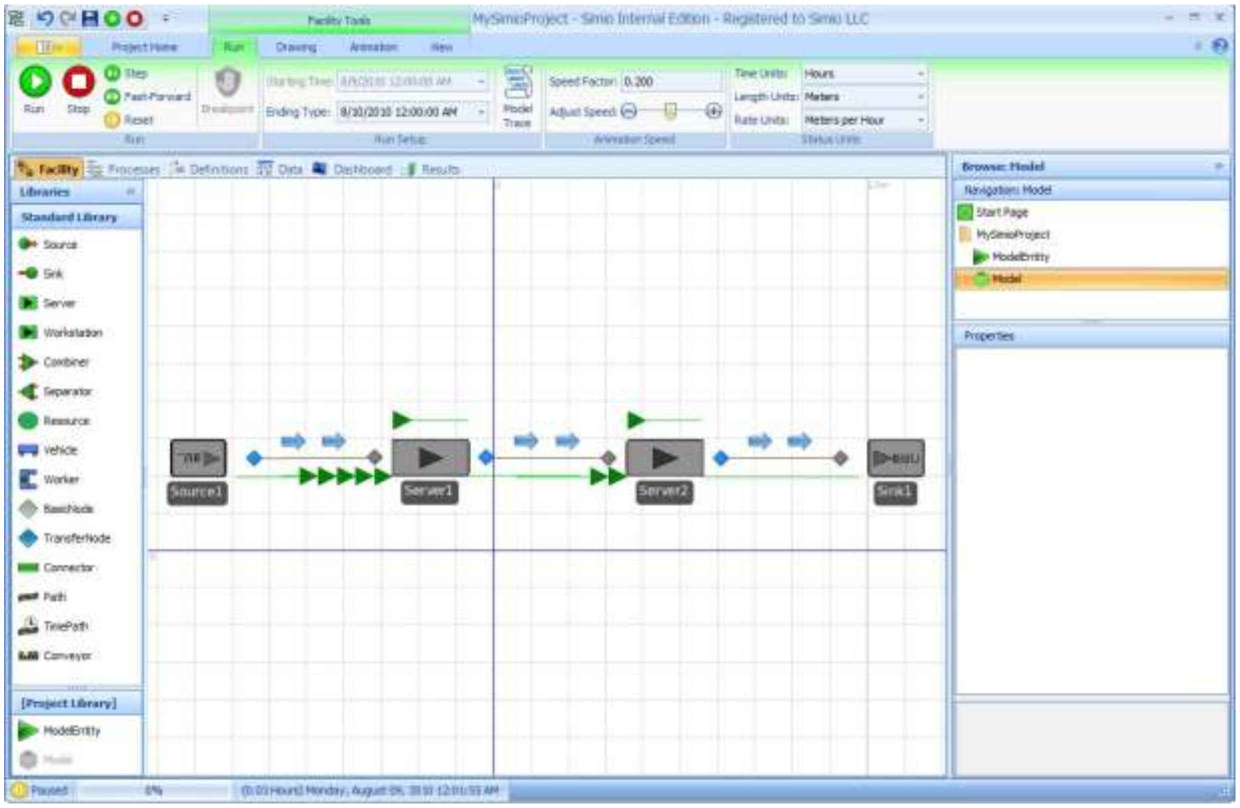
A Simple Flow Line Model

We will now use the Standard Object Library to build a model of a simple flow line in which entities arrive to the system, are processed through a sequence of two servers, and then depart the system.



We will model the arrival process of customers using the Source object, each server using the Server object, and departure process using the Sink object. We will use the Path object to model the pathways between these objects.

The mechanics of building this model is very simple. Open Simio and select New Model. Drag and place the Source, two Servers, and a Sink. Now double click on the Path object to enter path drawing mode and connect the output node of the source to the input node of Server 1, connect the output node of Server 1 to the input node Server 1, and finally connect the output node of Server 2 to the input node of the Sink. Click anywhere in the drawing space to terminate path drawing mode. Now click on the Run button on the left side of the Run ribbon and you will see your model start executing as shown below.



The green triangles are entities that represent the customers moving through the system. Note that each server has three green lines representing animations of the queues owned by the server. The animated queue on the left of the server is the input buffer where customers wait their turn to be processed, the animated queue above the server is the processing buffer where entities sit while being serviced, and the animated queue on the right is the output buffer where entities wait to leave the server. You can move and resize these queue animations. Note that these are animation only constructs and lengthening the animation queue changes the number of customers that can be animated in the queue, but not the actual number of customers that can be in the logical queue. The later is changed by selecting the server and changing the buffer capacities in the Property window. Also note that the actual number in the queue may exceed the number shown in the animated queue and it may be necessary to lengthen the animation queue to see all of the entities that are in the queue.

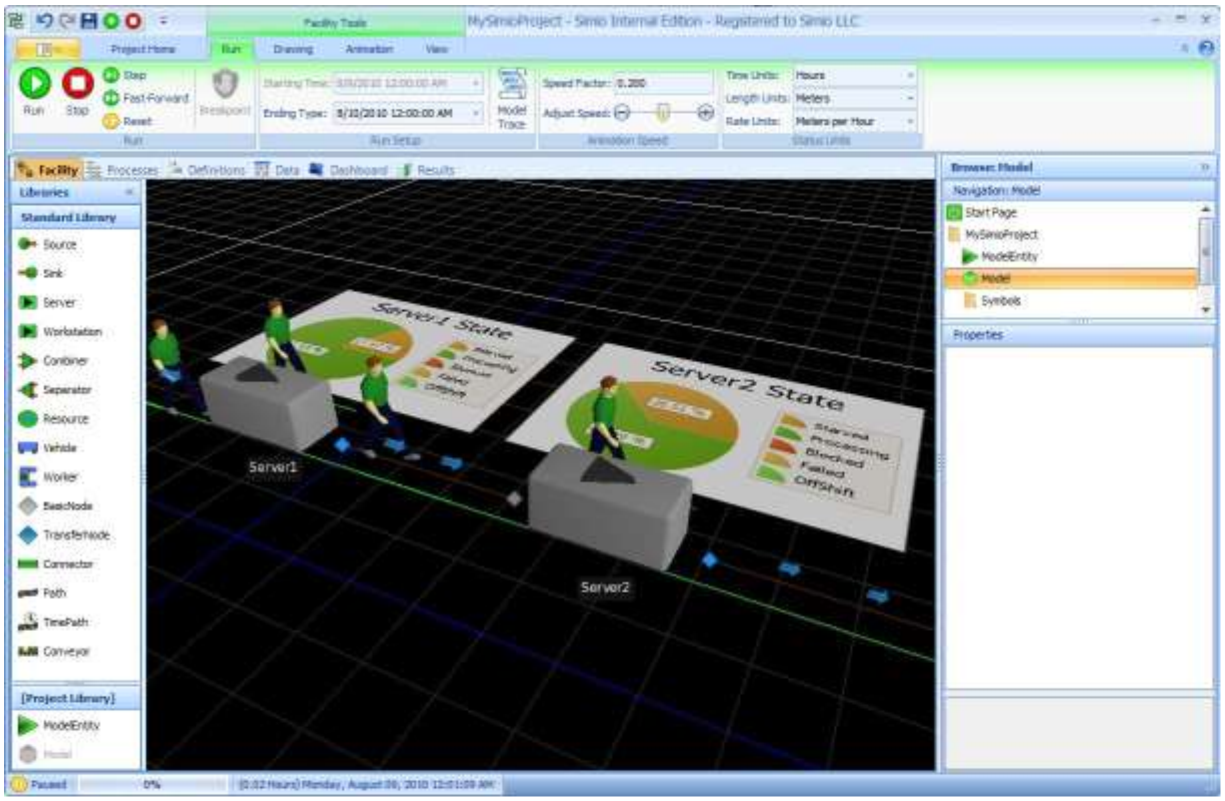
Note that you can pause and restart the simulation, or stop the execution of the model. You can also step an entity at a time, fast-forward the run without the animation, or reset the model back to its starting conditions. You can perform graphical edits such as moving a Server, adding a new path, etc., while the model is running, but you must stop the simulation to change any of the object properties.

At this point the model is running with all default property values. We will now modify some of the object properties so that we can see the impact of changing the waiting space between *Server1* and *Server2* on the upstream blocking of *Server1* by *Server2*. Click Stop to stop the model from running and click on *Server1* to display its properties in the Property window. Expand the *Buffer Capacity* category by clicking on the + sign, and set the *Output Buffer* capacity to 0 to eliminate any waiting space in the output buffer. Next click on *Server2*, expand the *Buffer Capacity* category, and set the *Input Buffer* capacity to 0 to eliminate any waiting space in the input buffer. With these buffers now set to zero, all entities between *Server1* and *Server2* are forced to be on the path connecting the two servers. Now click on this path and set the *Allow Passing* property to *False*, which will force the entities to back up behind each other on the path. If this path becomes backed up all the way to *Server1*, this server will be blocked from processing the next customer until space becomes available on the path.

Next we will add a status pie chart to each server so that we can animate the resource status of each server as the model runs. Click on *Server1* which will also automatically select the Symbols ribbon. Click on the small down arrow to the right of Status Pie, and then select *ResourceState* from the drop list. Click in the facility window to add the vertex for the top left of the pie, and then click again to add the vertex for the bottom right. This will add a pie chart that will animate the resource state for *Server1*. You can drag and resize this as needed. Repeat these same steps for *Server2*.

We will now improve our animation by replacing the green triangle with a 3D graphic of a person. Drag a *ModelEntity* from the Project Library on the left panel and place it in the facility window. Note that the *ModelEntity* is in the Project Library because it exists as a model in our project. You will see a green triangle with the name *DefaultEntity*. Note that if you select the Source object the *Entity Type* property specifies this *DefaultEntity* as the type of entity to create. The *DefaultEntity* is special in that Simio automatically creates this entity for you without you having to actually place it in your facility. This is done so that simple models will run without having to place an entity in the facility and specify the entity type on the source. This specially created entity becomes the first one that is placed in the facility and any additional entities that you place will be created only when you actually place them in the facility. Now click twice on the entity name and rename the *DefaultEntity* to *Customer* – note the name is automatically changed for the *Entity Type* property on the *Source* as well. Now that we have placed the default entity (now named *Customer*) we can change its graphical appearance. Note that by selecting the *Customer* you can resize it, or select a color or texture from the ribbon and then click on the entity symbol to apply the selection. To change the symbol click on the down arrow in the symbol pane to drop the list of symbols, scroll through the list and select a symbol of a person. The green triangle will now be replaced by that symbol. You may wish to switch to 3D (by pressing the 3 key) to view and resize the symbol within the facility.

With these changes our running animation now appears as follows. Since *Server1* is blocked by *Server2* whenever the pathway between them is full you can alter the amount of blocking that occurs for Server1 by moving the servers to change the length of the pathway between them.



Defining Model Properties and Experiments

There are two basic modes for executing models in Simio. The first mode is the interactive mode that we have been using up to this point. In this mode you can watch the animated model execute and view dynamic charts and plots that summarize the system behavior. This is useful for building and verifying/validating the model as well as getting general insight into how the system will perform. Once the model has been validated the next step is typically to define specific scenarios to test with the model. In this case we have no interest in the animation and we would like to replicate each scenario to account for the underlying variability in the system and to reach statistically valid conclusions from the model. We will now turn our attention to the experimentation mode of Simio.

In the experimentation mode we define one or more properties on the model that we can change to see the impact on the system performance. These properties might be used to vary things like conveyor speeds, the number of operators available, or the decision rule for selection the next customer to process. These model properties are then referenced by one or more objects in the model.

Continuing with our simple example we will add a model property that we can reference and use to control the processing time on *Server2*. We will then run some experiments to see the impact of different processing times by changing the value of this model property. One way to manually add this property to the model is to select the Definitions tab for the model, select the Properties panel on the left, click in the ribbon on the down arrow for the Standard Property, and select Expression. We could then return to the Facility window and select this newly created property for the *Processing Time* for

Server2. However a short cut method to accomplish these same steps is to right click on the *Processing Time* property in the Property window for *Server2*, and select Create New Reference Property. This will create a new reference property with the default name *ProcessingTime*, and also specify this as the value for the *Processing Time* property. Hence we create the new property and set the reference to it in a single step.

Now that we have our new referenced property we will define an experiment to see the impact of varying this property. Add a new experiment by right-clicking on Model in the navigation tree, and selecting New Experiment. This will create a new experiment with default name *Experiment1* and also select this experiment as the active project component. You can easily return to your model by clicking on Model in the navigation tree. You can create as many experiments as you like for your model. For example you might have one experiment to processing times, and another experiment to evaluate buffer sizes or staffing levels.

Our experiment shows a table, where each row of the table is a scenario to be executed. Note that each scenario has a check box (enabled/disabled), name, status (initially Idle), and replications required and completed, and a column for each referenced property on the model. The properties which are referenced by the model are referred to as Controls since they control the inputs to the model for the scenario being run. In this example we have a single referenced property named *ProcessingTime* that is used to control the processing time for *Server2*.

We can also add one or more Responses or Constraints to our experiment. A Response can be any valid expression and is typically a key performance indicator (KPI) that is of particular interest to us in comparing the scenarios. Although the Pivot Grid and Reports will provide detailed results for the model, we typically have a few keys parameters that we would like to display directly in the experiment table. We can also select a specific response to be the Primary Response for the experiment that is displayed in the Response Chart for the experiment. A Constraint is an expression that must be satisfied for the scenario to be valid. Both Responses and Constraints may be used by custom add-ins for defining and evaluating the results from an experiment. For example the OptQuest add-in may be used to perform an automatic search to optimize the Primary Response, subject to any constraints that have been defined.

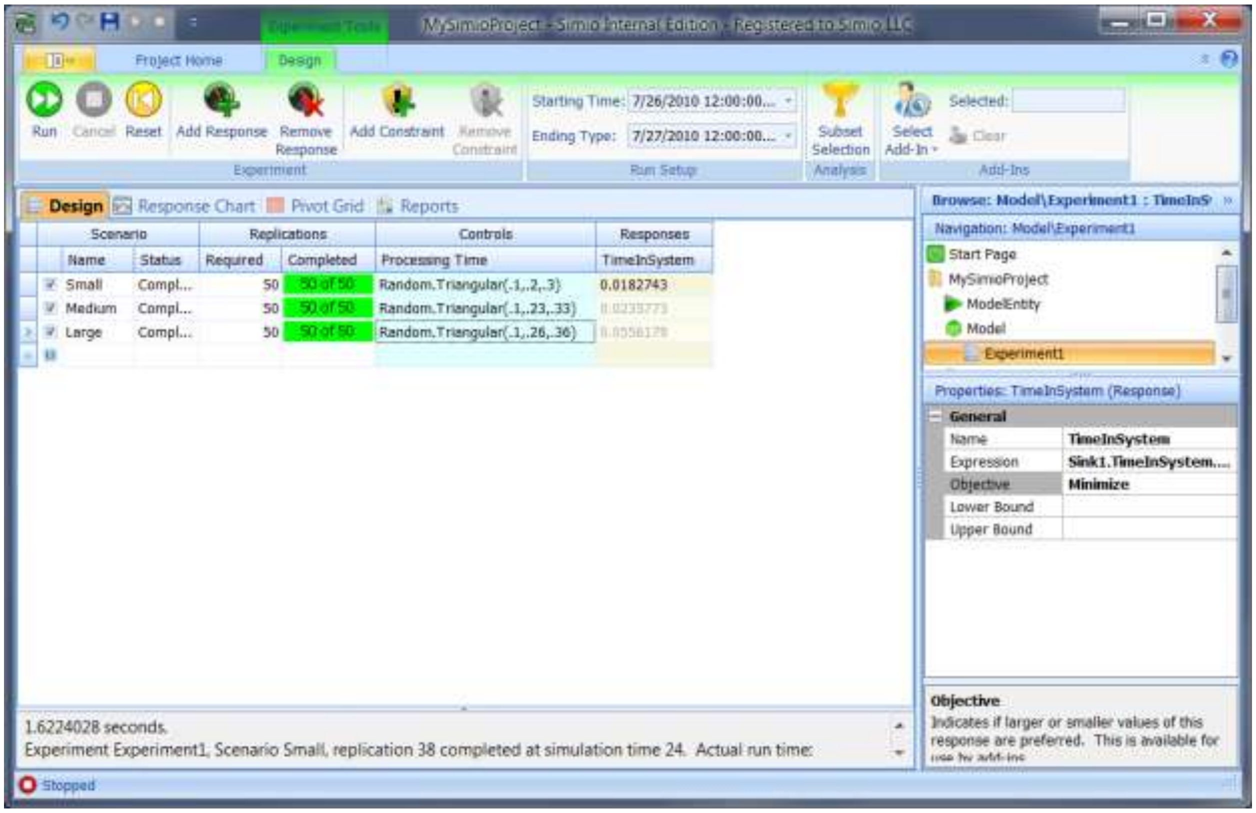
Click on *Add Response* in the ribbon to add a new response to your experiment. In the property grid change the response name to *TimeInSystem*, enter the response expression as *Sink1.TimeInSystem.Average*, and select the Objective as Minimize.

We will now define and run three scenarios which we will name *Small*, *Medium*, and *Large*. Enter these names in the *Name* column of the table and change the number of required replications to 50. In the *Process Time* column change the parameters of the triangular distribution for the *Medium* scenario to *.1, .23, .33*, and in the *Large* scenario change these values to *.1,.26,.36*.

Now click on the Run button to initiate the batch running of these scenarios. When you do so you will see the status for one or more scenarios Running, and the remaining ones listed at Pending. As each scenario completes its 50 replications it status will change from Running to Completed. If you are running on a multi-core processor Simio will automatically assign replications to be executed across each core of the computer. For example if you have a quad-core processor Simio will run four replications at a time.

Interpreting the Results

Your specific results for this example will depend upon the length for your paths and size of your customers. However the results should look similar to the following:



Starting Time: 7/26/2010 12:00:00...
Ending Type: 7/27/2010 12:00:00...
Selected:
Run Setup

Scenario		Replications		Controls	Responses
Name	Status	Required	Completed	Processing Time	TimeInSystem
✓ Small	Compl...	50	50 of 50	Random.Triangular(.1,.2,.3)	0.0182743
✓ Medium	Compl...	50	50 of 50	Random.Triangular(.1,.23,.33)	0.0235773
✓ Large	Compl...	50	50 of 50	Random.Triangular(.1,.26,.36)	0.0556178

Browse: Model\Experiment1 : TimeInS
Navigation: Model\Experiment1

Properties: TimeInSystem (Response)

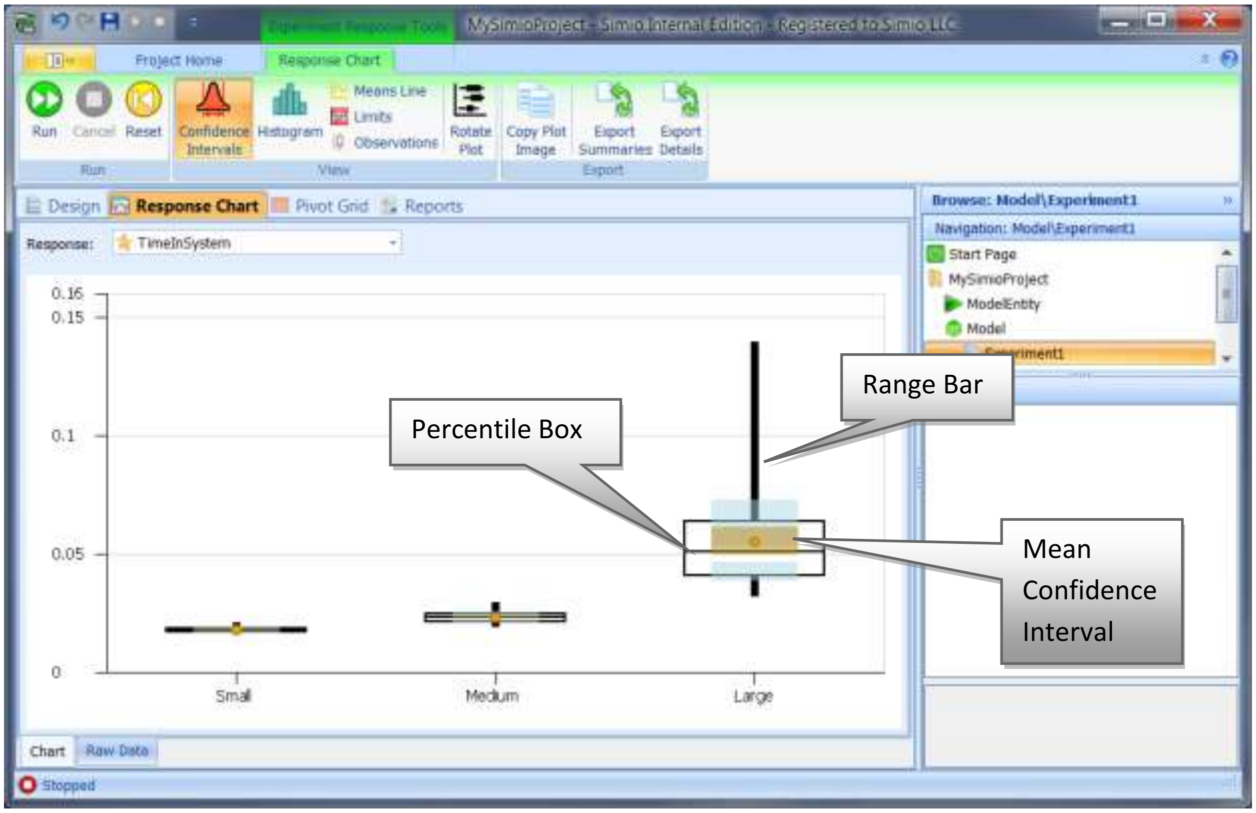
General	
Name	TimeInSystem
Expression	Sink1.TimeInSystem....
Objective	Minimize
Lower Bound	
Upper Bound	

Objective
Indicates if larger or smaller values of this response are preferred. This is available for use by add-ins

1.6224028 seconds.
Experiment Experiment1, Scenario Small, replication 38 completed at simulation time 24. Actual run time:

Note that in this case the *Medium* and *Large* responses for *TimeInSystem* are grayed out. This is the result of clicking on the Subset Selection button in the ribbon which causes Simio to automatically separate the scenarios into two sets for each response: those that might be the best (shown in solid), and those that can be discarded as not the best (shown grayed-out). This indicates that the *Small* scenario can be statistically selected as the single "best" scenario based on minimizing this response. If the response has more than one member of the "could be best" you can narrow the selection down to a single scenario using the *Select Best Scenario using KN* add-in. This add-in employs the sequential selection method by Kim and Nelson (S. Kim and B. L. Nelson, "A Fully Sequential Procedure for Indifference-Zone Selection in Simulation," *ACM Transactions on Modeling and Computer Simulation* **11** (2001), 251-273) to automatically make the required additional runs to narrow the selection down to a single best scenario.

You can also gain additional insight into your responses by viewing the Response Chart for the primary response. Click on the Response Chart tab which brings up the following panel and ribbon.



The Response chart shows a SMORE chart (an enhanced version of Nelson's MORE chart) that graphically displays a number of different summary statistics for each scenario. The black rectangular box shows the region containing observations between a lower and upper percentile point (by default .25 and .75). The black bar shows the range of all values. The tan box is the confidence interval on the mean, and the blue boxes are confidence intervals on the lower and upper percentile points. The dark tan area is where the confidence intervals overlap. You can also show individual observations, a histogram, limits, or a line plot by toggling these on in the ribbon. You can also rotate the entire chart to view it either vertically or horizontal.

Whenever you save your project the results for each experiment are also saved. You can discard the results by clicking on the Reset button in the Design ribbon. After running an experiment you can also view the results and add additional replications (by changing the Replications Required) to reduce the half-width of the confidence intervals.

You can also view the detailed results for a wide range of statistics that are recorded by default during the run under either the Pivot Grid or the Reports tab. The Pivot Grid is convenient for quickly drilling into results of interest by letting you interactively analyze the results in the form of a dynamic rotatable table. You can drag and drop columns in the table to rotate or "pivot" the data. You can also filter and sort the information that is shown. This is similar to features found in the pivot table provided by Microsoft Excel. You can also export the results to external programs such as Excel. The Reports tab displays a more traditionally formatted report and provides flexible visual formatting for inclusion on web pages or in printed documents and is useful in presenting results to others.

The results in the Pivot Grid and the Reports show the average, minimum, maximum, and half width for each of the variables that have been recorded during the simulation. By default the objects in the Simio Standard Library automatically record a wide range of statistics. As you will see later you can selectively control the statistics that are recorded.

Summary

This chapter has introduced the basic modeling concepts of Simio. We have introduced the concept of a Simio project as a collection of models and associated experiments. We have also introduced the basic concept of an object and how it is used as a building block for rapidly building and running 3D models in both an interactive and experimentation mode. In subsequence chapters we will expand on this basic knowledge to fully explore the modeling power of Simio.

Chapter 2: Network Travel

Overview

In Chapter 1 we introduced the basic concepts for building and running object-based models in Simio. In our first example we modeled a single line of flow with entities arriving from the Source, proceeding through the two in-line Servers, and then departing at the Sink. In this chapter we will look at Simio features for controlling entity and transporter movements. Note that transporters are a special case of entities: they are entities that can also pick up, carry, and drop off other entities. Hence our description of entity movements will also apply to transporter movements.

Entities may travel in either free space or over a network of links and nodes. In free space travel an entity may move without the aid of other objects by setting its direction, speed, and acceleration. In this case the movement is only governed by the entity and it can freely and independently move through 3D space. In the case of network travel the entity moves over a constrained set of links and nodes. In this case the movement is governed by both the entity and the corresponding links and nodes. Note that different types of links and nodes can produce different types of travel behavior based on the internal models for those links and nodes. For example one link might impose conveyor-like behavior, and another link might allow for independent movement and passing. In this chapter we will focus on network travel.

Entities

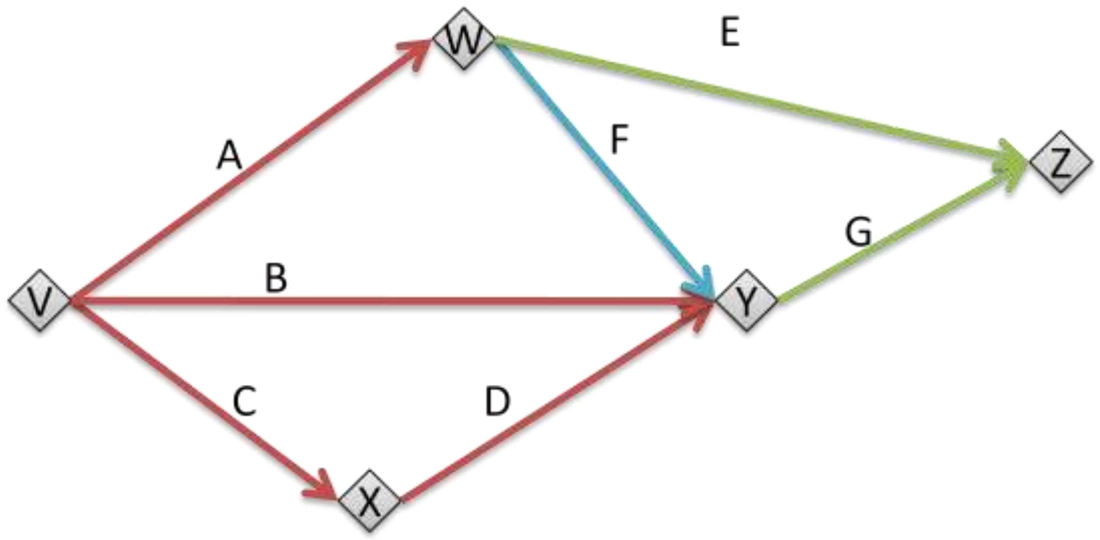
Entities are dynamic objects that can be created and destroyed, travel over networks, and enter and depart fixed objects thru their associated node objects. The dynamic entity objects are created from an entity instance. You typically place one or more entity instances in your model by dragging them in from your Project library or another custom library. The entity instance has a stationary location and is used as a "template" for generating dynamic entities that move through the model. Each of the dynamic entities may have both properties and states. The properties are defined by the entity instance and are unchangeable during the run and shared across all the dynamic entities. However each dynamic entity will have its own values for its states which may change as the model runs.

For example, assume we have an entity definition named *Person* that has properties named *Sex* and *HairColor*, and states named *Income* and *MaritalStatus*. Assume that we place two instances of *Person*; one we name *CustomerTypeA* and the other we name *CustomerTypeB*. We can specify the values for *Sex* and *HairColor* for either *CustomerTypeA* or *CustomerTypeB*. All of the dynamic entities that are generated for *CustomerTypeA* will all have the same value for these properties, and these values cannot change during the run. In the same way all of the dynamic entities that are generated for *CustomerTypeB* will have the same non-changeable values for *Sex* and *HairColor* as defined by the statically placed entity instance for *CustomerTypeB*. However each dynamically created *Person* (from either *CustomerTypeA* or *CustomerTypeB*) will have its own unique value for *Income* and *MaritalStatus* and these values may be changed during the run.

Networks

A network is a collection of one or more links over which entities travel. In Simio you can define as many networks as you need, and a link can be a member of multiple networks. This latter point is important for modeling situations where different entities travel on their own networks, but share a common pathway: e.g. workers and forklift trucks sharing a common aisle. For network travel an entity must be assigned to a specific network over which they are permitted to travel. The collection of all links is automatically assigned to a special network called the Global network. By default all entities are assigned to travel on the Global network (i.e. they can travel on any link). The entity may change its travel network at any time during the running of the simulation.

Consider the following graph of nodes and links, in which links A, B, C, D, and F are in network 1, and links E, F, and G are in network 2. Note that in this case we have link F common to both networks. The red and blue links correspond to network 1, and the green and blue links correspond to network 2. Note that the arrows in the graph denote unidirectional links. We will discuss bi-directional links later in this chapter.



Network 1: A, B, C, D, F

Network 2: E, F, G

Global Network: A, B, C, D, E, F, G

By assigning entities to networks we can control where in the system they can travel. For example we might assign a person entity to the Global network, an AGV to network 1, and a forklift truck to network 2. In this case people, AGV's, and forklift trucks could all travel from W to Y along link F. The initial network is assigned to an entity by clicking on the entity instance in the facility window (you must first place the entity instance by dragging it from the Project library) and then setting the *Initial Network* property.

In Simio a link may be added to an existing or new network or removed from an existing network by right clicking on the link. The links that belong to a specific network can be highlighted using the View Networks drop list on the View ribbon. If multiple networks are selected for highlighting, then either the Union (links that are a member in one or more of the selected networks) or Intersection (links that are a member of all selected networks) can be highlighted.

Node Routing Logic

Whenever an entity departs a node with more than one departing link in its network then the decision of which link to travel along is based on the node routing logic. For example an entity traveling on network 1 and departing node V will have 3 links to choose from based on its routing logic. However an entity traveling on network 1 and departing node W has only one option: i.e. link F.

In large and complex models we often have alternate pathways through the system and must specify routing logic for controlling the movement of entities through the system. In the case of the Standard Library the routing logic for selecting between multiple candidate links is specified by an outbound link rule and outbound link preference. The outbound link rule specifies how the link is to be selected, and the outbound link preference specifies if all links are to be considered (*Any*), or only those that are currently available (*Available*). An available link is one that can immediately be entered. The outbound link rule is specified as either *Shortest Path* or *By Link Weight*.

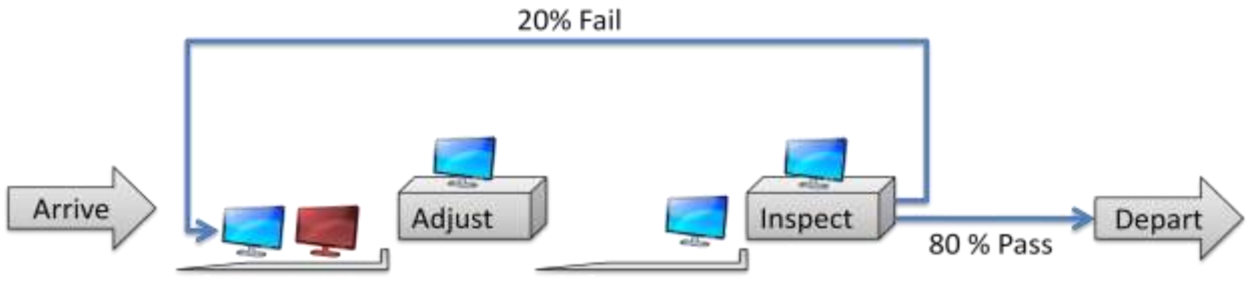
In the case of shortest path the entity will select the path that is along the shortest path to its destination (note that we will discuss the options for setting the destination for an entity in a moment). Hence a person traveling on the Global network from V with its destination set to Z would select link B at node V (assuming B is available or the *Any* option is selected). If the outbound link rule is specified as shortest path but the destination is not assigned, then the link is selected by link weights.

When outbound link rule is specified as By Link Weight (or no destination has been set), then the link is selected randomly using the weights specified for each candidate link. The probability of a given link being selected is equal to its weight divided by the sum of the weights for the candidate links. All links have a selection weight property that can be specified as a number or any valid expression. In the simple case we can use these link weights like percentages or probabilities. For example if one link has a weight of 80 (or .8) and the other a weight of 20 (or .2), then the links will be selected randomly with an 80/20 split.

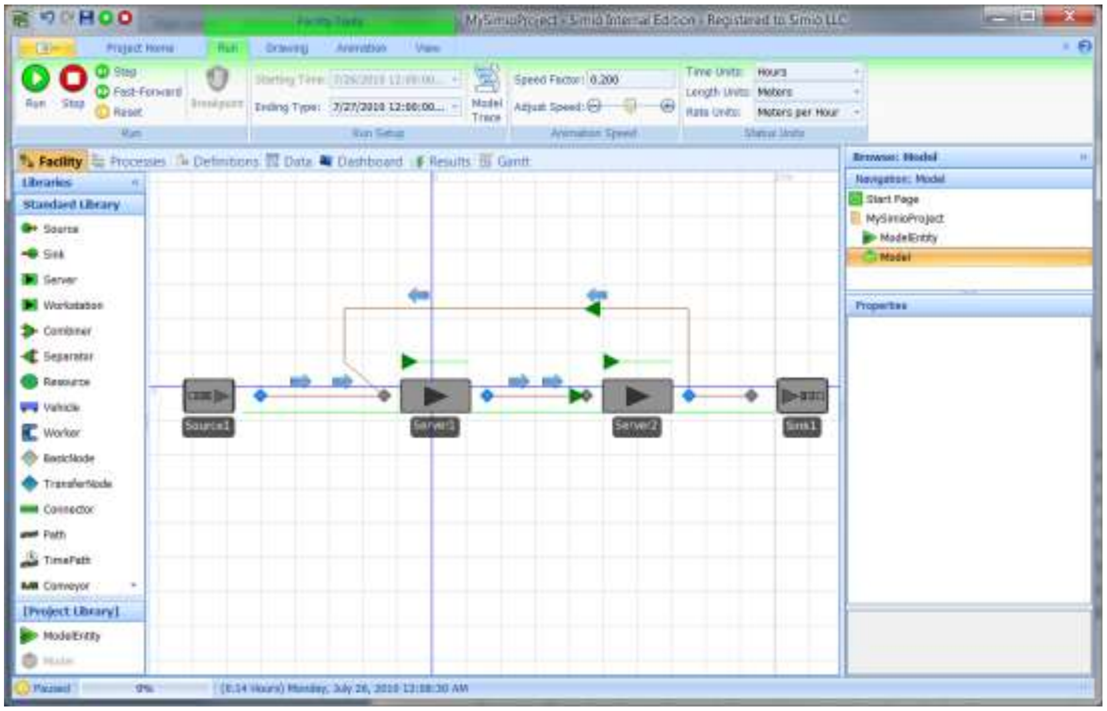
In Simio a logical expression (e.g. *X > 2*) will return a 1 if true, and 0 if false. This makes it very convenient to use logical expressions for specifying link selection weights. Note that in this case the weights will dynamically change during the simulation based on the value of the logical expression. For example, an expression *Lathe.InputBuffer.Contents.NumberWaiting == 0* will have a selection value of 1 if the input buffer for the Lathe is empty, otherwise it will have a selection weight of 0.

Example: Routing by Link Weights

We will now build simple model of a TV inspection and adjustment process to illustrate the use of link weights for entity routing. Consider the following example in which TV's arrive to an adjustment process, then undergo an inspection in which 20% fail inspection and are re-routed back for adjustment. We will have the rejected TV's turn red until re-inspection has been completed.

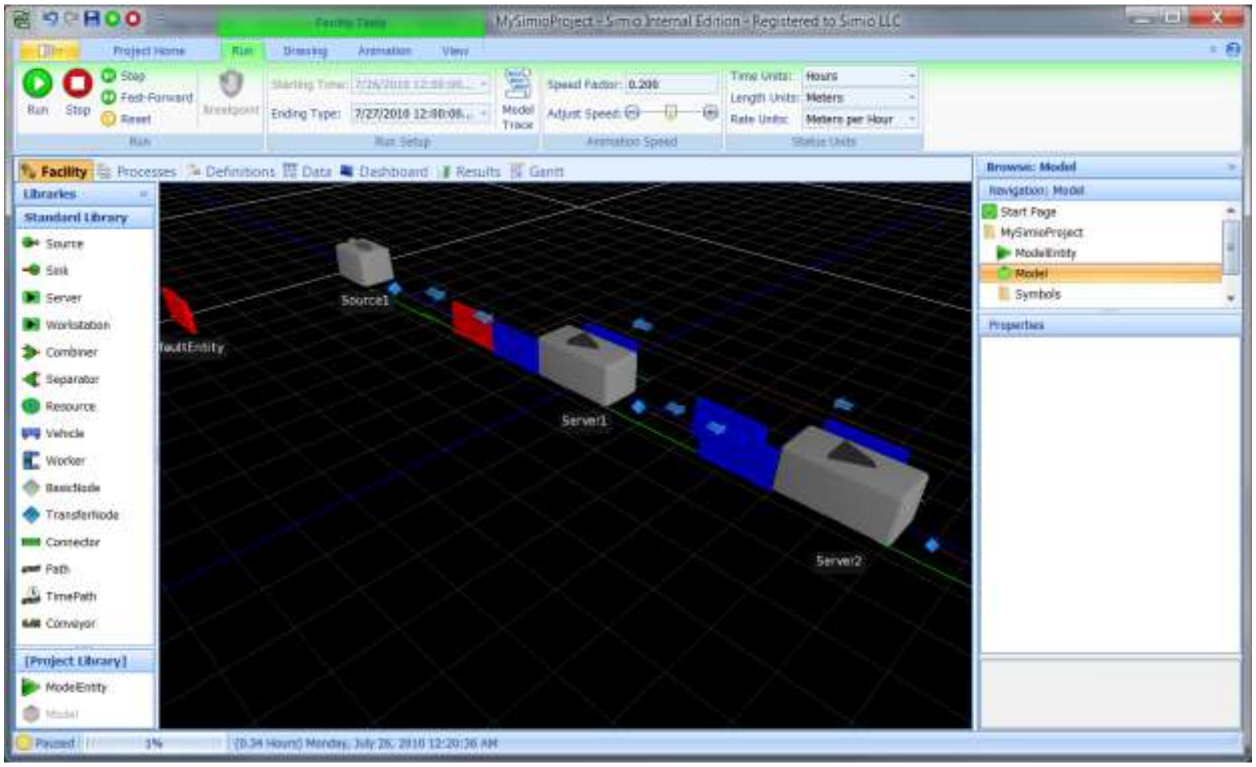


Open up Simio with a new project and place a Source, two Servers, and a Sink into the facility window. Rename the Source and Sink to *Arrive* and *Depart*, and the Servers to *Adjust* and *Inspect*, and draw paths connecting the output node of the Source to the input node of *Adjust*, the output node of *Adjust* to the input node of *Inspect*, the output node of *Inspect* to input node of *Adjust*, and the output node of *Inspect* to the Sink. Select the return path from the output node of *Inspect* to the input node of *Adjust* and set its selection weight property to 20, and select departure path from the output node of Inspect to the input node of the Sink and set its selection weight to 80. If you now click on the Run button you will see entities being randomly routed from the *Inspect* server based on the specified link weights.



Next we will use Google warehouse to improve our animation by replacing the green triangles with a symbol of a TV, and also change the color of this symbol to red when a TV fails inspection, and then back to blue when a TV passes inspection. Drag out an instance of the *ModelEntity* from the Project library and place it in our facility. Select the entity instance, rename it *TV*, and with the TV selected click on Download Symbol in the Symbols ribbon and search for and select a *TV* symbol from Google Warehouse. With the *TV* symbol selected click on Add Additional Symbol in the Symbols ribbon; this adds a second symbol to the list of symbols for this entity. You can change between these symbols by selecting the drop list below Active Symbol and then clicking on the symbol you would like to be active. Make symbol 0 active and color it blue, and then make symbol 1 active and color it red.

To change between these symbols during the run we will make an assignment to the *ModelEntity* state variable named *Picture*. When *Picture* is set to 0 the entity will be drawn using symbol 0 (blue) and when *Picture* is set to 1 the entity will be drawn using symbol 1 (red). To change to the red symbol upon failure select the return path (*Path4*) from *Inspect* and click on the button in the *State Assignments -> On Entering* state assignment property to open the assignment editor. Click on Add button to add a new assignment, specify the state as *ModelEntity.Picture*, and specify the value as 1. This will cause the *ModelEntity* state *Picture* to be assigned a value of 1 upon entering the return path. To restore the entity to the blue symbol following adjustment click on the path departing Adjust, and click on the button in the *On Entering* state assignment property to open the assignment editor. Add an assignment to set *ModelEntity.Picture* to 0 (blue). This will cause all *ModelEntities* entering the departure path from Adjust to be displayed as blue. If you now rerun the model you will see the TV's changing between red and blue as desired.



Setting the Entity Destination

Whenever the routing logic is based on the shortest path a destination is required for the entity. When using the Standard Library the destination for an entity may be set using the TransferNode by specifying the *Entity Destination Type* and its associated property values. Since the TransferNode is always used for the output side of the Standard Library fixed objects (Source, Server, Combiner, etc.), you can always specify the destination for an entity just as it departs any of the fixed objects in the Standard Library. To specify the destination you click on the TransferNode on the output side of the fixed object and specify the *Entity Destination Type*.

There are four options for specifying the *Entity Destination Type*. The first option is to *Continue* and specifies that the entity is to continue without reassigning the destination. This is the default option and is useful when the entity already has its destination set.

A second option is to specify a *Specific* destination. In this case a required associated property is exposed for selecting the *Node Name* from the drop list. The node maybe be a simple name for a free standing node (e.g. *IntersectionA*), or a compound name (e.g. *Input@Server1* or *Output@Server1*) for a node that is attached as the input or output node of a fixed object. Compound node names are always specified using the format *NodeName@ObjectName*.

The third option for specifying a destination is *Select From List*. In this case we are dynamically selecting from a list of candidate destinations based on several criteria, which includes a *Selection Goal* (e.g. *Smallest Distance*, *Cyclic*, etc.), a *Selection Condition* that must be true for the node to be considered as a candidate for selection, and a *Blocked Routing Rule* that specifies if an “unblocked” node is required or preferred. An unblocked node is one that can immediately accept the entity. For example a Server with a finite buffer that is full would block any incoming entities.

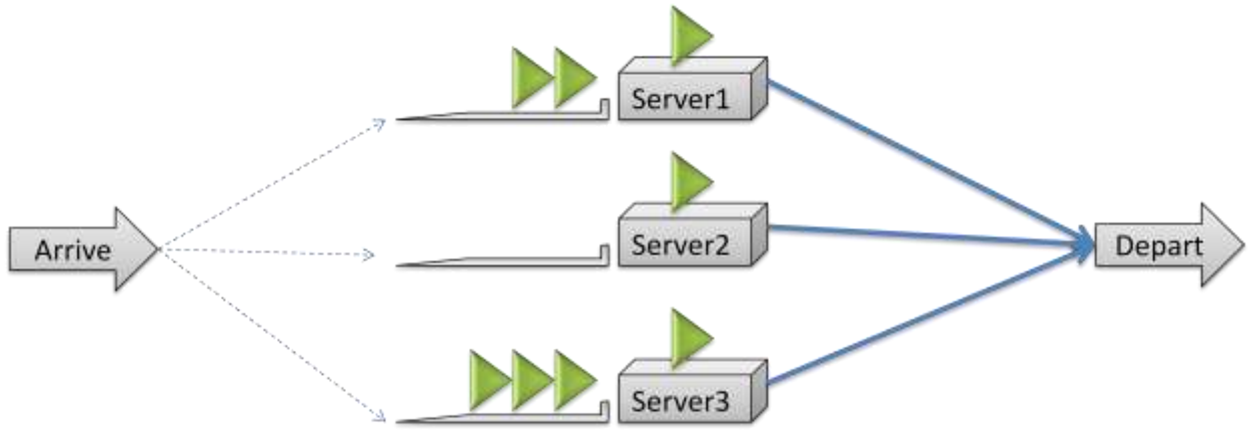
The fourth option is to specify that the destination is to be set *By Sequence*. In this case we have defined a specific visitation sequence (e.g. Drill, Lathe, Inspect, Depart) for each entity and we would like to set the destination to be the next node in this sequence. This is useful for modeling job shops in which each entity has a different travel path through the system.

Regardless which method is used to set the destination for the entity, the shortest path routing logic can then be used to select the link that is on the shortest path to that destination. Note that although the use of the shortest path rule requires a destination, having a destination does not force you to use the shortest path rule: i.e. you can still employ link weights to control flow at one more locations along the way.

The *Select From List* and *By Sequence* options are both very useful and powerful methods for setting the destination for an entity. We will now illustrate each of these more advanced methods with an example.

Example: Select From List for Dynamic Routing

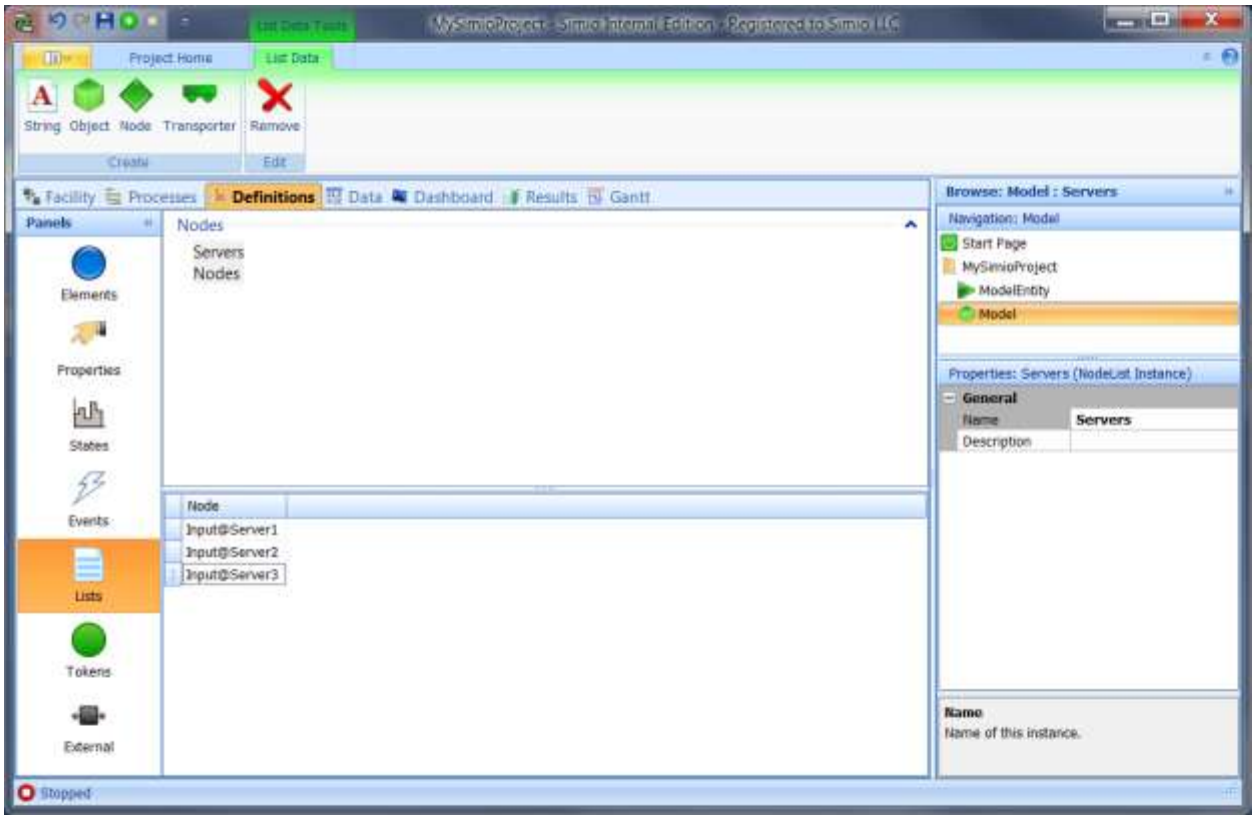
In this example we will use the *Select From List* routing option to send the arriving entities to the server with the fewest number of entities waiting in the queue. Consider the following system with arrivals being dynamically directed to one of three servers based on the smallest queue length. *Server1* has a constant processing time of 20 minutes. *Server2* has a random processing time in minutes with a triangular distribution and a minimum of 1, mode of 3, and maximum of 8. *Server3* has a processing time of .1 minutes.



Open up Simio and place a Source, three Servers, and a Sink. Use a Path to connect the Source to the input node of each of the three servers, and also connect each of the Server output nodes to the Sink. Edit the *Processing Time* for each of the servers (select the *Processing Time* in the Property window and click on the down arrow to open up the Expression Editor and begin typing) and also set the *Input Buffer* capacity for each Server to zero. This will force entities entering the Server to wait on the path since there is no input buffer available. Change the *Allow Passing* option on the Paths connecting the output node for the Source to the input nodes on the Server to *False* so that the entities will "queue up" along the path. Note that you can select the first, and then use Control-Click to add the second and third paths to the selection set, and then simultaneously change this property for all three paths. This same approach can be used to simultaneously set the input buffer sizes to zero for the three servers.

Before using the *Select From List* option for selecting the destination we must first define our list of target nodes. In this case our target nodes are *Input@Server1, Input@Server2,* and *Input@Server3*. We will create a list of these nodes for selecting our destination.

To define a list in Simio click on the Definitions window tab just below the ribbons, and then click on the Lists icon in the panel selector on the left. In the Create section of the List Data ribbon we can click on the icons to create a string, object, node, or transporter list. String lists are useful for creating properties or states that have specific named values (e.g. *Small, Medium, Large*). Object lists are useful for selecting specific objects to interact with – e.g. selecting an operator to seize. Transporter lists are useful for selecting a particular transporter to request a pickup. In this case we click on the node icon to create a node list of Server input nodes to select from for routing entities. We will give this node list the name Servers, and populate it with the names of the input nodes for the three servers as follows:



Nodes
Servers
Nodes

Node
Input@Server1
Input@Server2
Input@Server3

Properties: Servers (NodeList Instance)

General	
Name	Servers
Description	

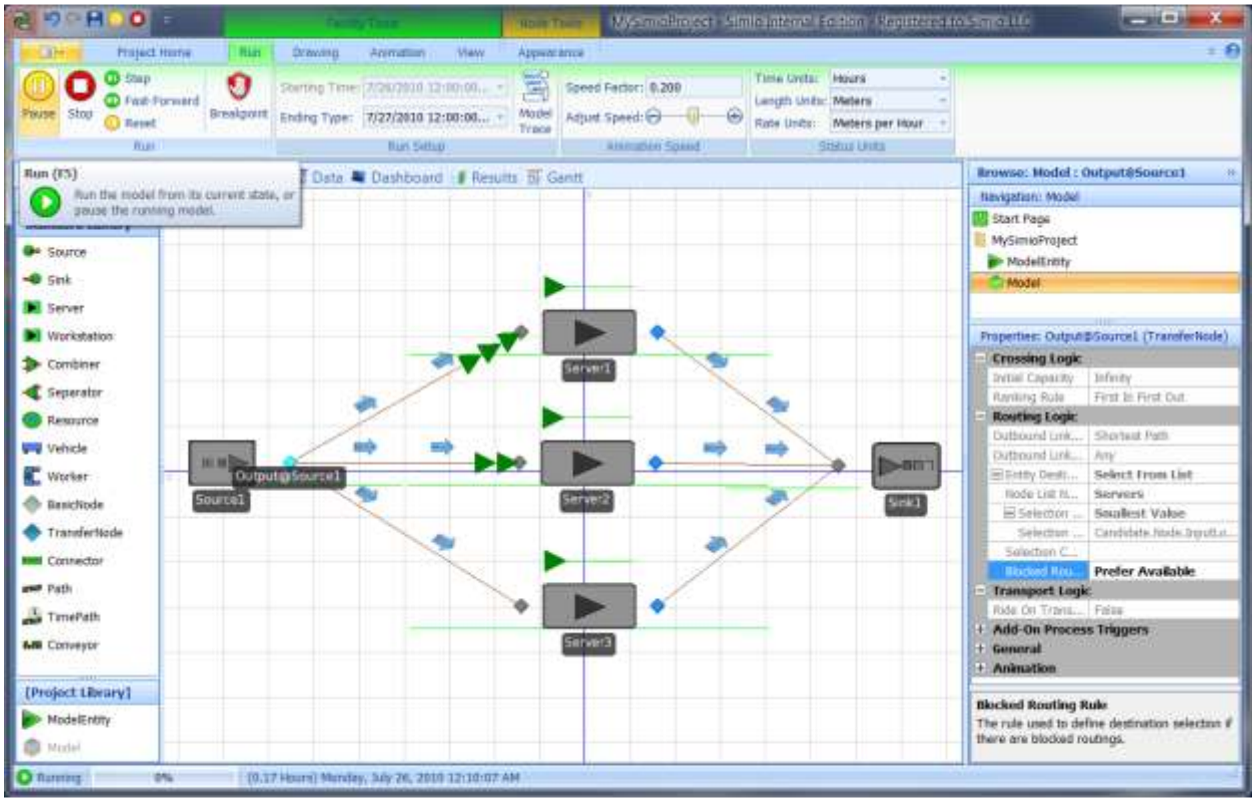
Name
Name of this instance.

Now that we have defined our list, we will return to the facility model by clicking on the Facility window tab. Click on the output node for the Source to specify the routing logic from this node to the three Servers. In the Routing Logic section of the Property window change the *Entity Destination Type* to *Select From List*, and specify the *Node List Name* as the newly created node list named *Servers*. Next set the *Selection Goal* to *Smallest Value* and keep the default Selection Expression as:

Candidate.Node.InputLocation.Overload

Expressions are normally evaluated in the context of the parent object or the entity object executing the process logic, which in this case is our main model or the entity being routed. When we are searching the nodes in the list we want to tell Simio to use the context of the candidate object we are looking at in the search, and not the parent object or routing entity. The keyword *Candidate* is used for this purpose. The next part of the expression is telling Simio that the object type being examined is a class *Node*. The *InputLocation* specifies a reference to an input location at this node, typically the input or processing station at the associated object. Finally the function *Overload* is a built in function on the Node class that returns the overload at this node. The overload is defined as the number of entities at this location, plus the number waiting to enter this location, plus the number of entities traveling with this node as their destination, minus the capacity at this location. Note that a positive number indicates the input location is currently overloaded (more there or on the way than the available capacity). A negative value indicates that capacity is still available based on those at or traveling to the Server.

Although this will generally balance the load between the three servers, we can make one additional change to further improve the balance by specifying the *Blocked Routing Rule* as *Prefer Available*. Note that we can have a situation where both *Server1* and *Server2* are busy, *Server3* is idle, but no one is currently travelling to any of the servers. By specifying the *Prefer Available* rule we will select *Server3* in this instance, which produces a more balanced flow of work to the three Servers. Our final model with these options set is shown below:



Browse: Model : Output@Source1

Navigation: Model

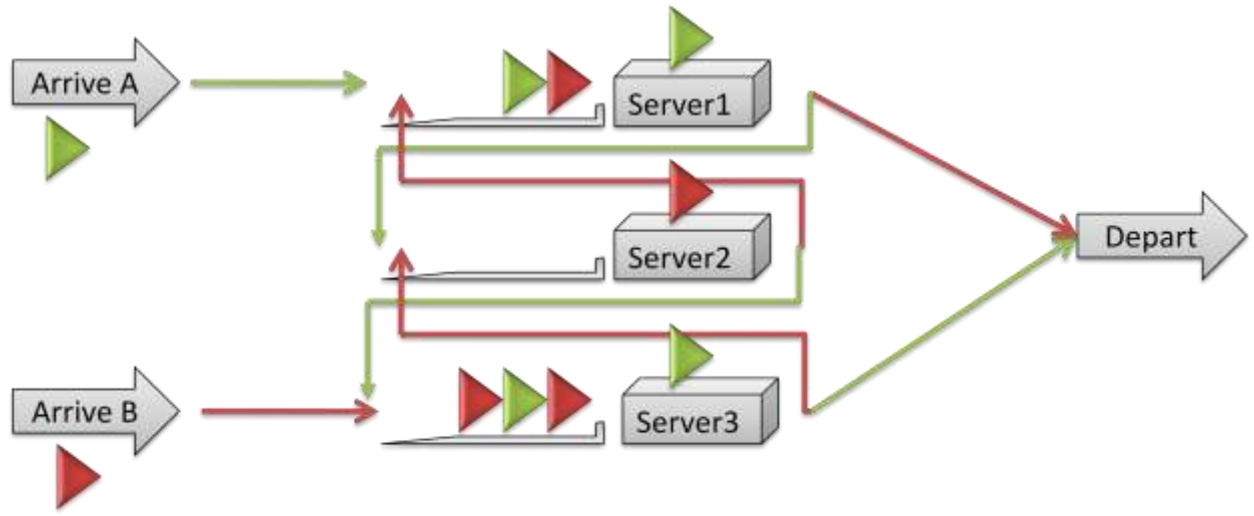
Properties: Output@Source1 (TransferNode)

Crossing Logic	
Initial Capacity	Infinity
Ranking Rule	First In First Out
Routing Logic	
Outbound Link...	Shortest Path
Outbound Link...	Any
Entity Desti...	Select From List
Node List N...	Servers
Selection ...	Smallest Value
Selection ...	Candidate.Node.InputLo...
Selection C...	
Blocked Rou...	Prefer Available
Transport Logic	
Ride On Trans...	False
Add-On Process Triggers	
General	
Animation	

Blocked Routing Rule
The rule used to define destination selection if there are blocked routings.

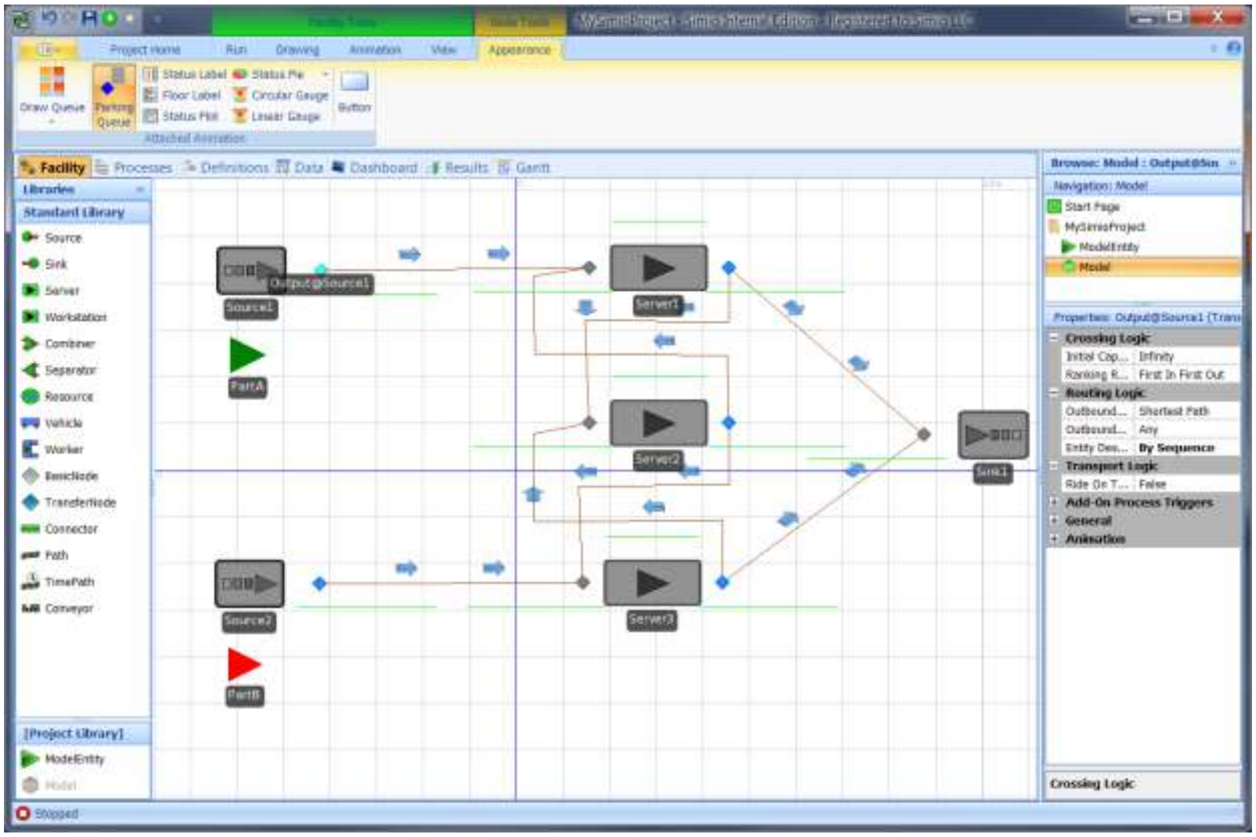
Example: By Sequence

In this example we will use the *By Sequence* option for setting the *Entity Destination* property. This option is useful for modeling situations in which an entity follows a specific sequence of destinations through the model. For example in a job shop each part type might have its own production sequence through the facility. To illustrate this functionality consider the following example where we have two different part types being processed across three different servers. Part type A is processed in the forward direction (*Server1, Server2, Server3*) and part type B is processed in the reverse direction (*Server3, Server2, Server1*).

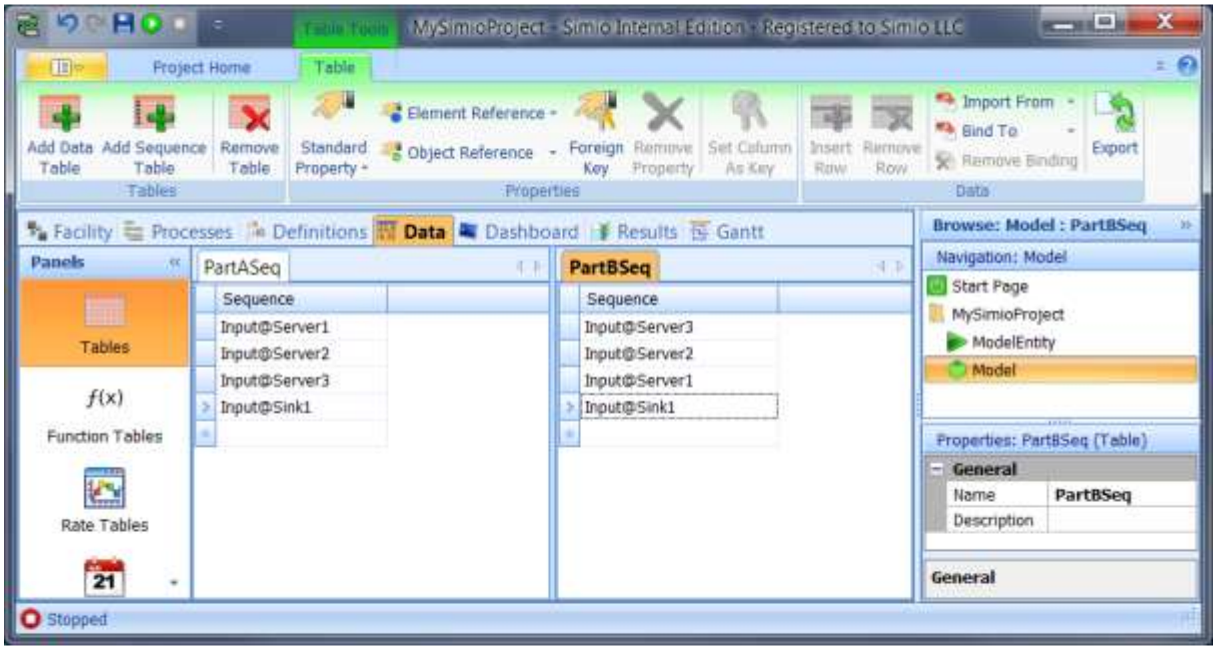


In this particular example the two part types do not share common paths. *PartA* will always travel on a distinct set of paths (shown in green), and *PartB* will always travel on a separate set of paths (shown in red). Hence in this case it would be possible to model this entity flow using two sub-networks. We would assign the green paths to *NetworkA*, and the red paths to *NetworkB*, and have the two part types follow their own sub-network through the system, creating the desired flow through the system. However this approach does not work in all cases: e.g. if *PartB* had a sequence *Server3*-*Server2*-*Server3*. Routing by sequence provides the flexibility needed to model these more complicated flows.

Begin by opening Simio, creating a new project, and placing the two Sources, three Servers, and Sink. Also drag out two entity symbols from the Project library and rename them *PartA* and *PartB*. Next we will color *PartB* red by clicking on the entity symbol, selecting the red color from the Symbols ribbon, and then clicking on the entity symbol to apply the color. Double click the path symbol in the Standard Library and draw the forward paths for *PartA*, and then continue drawing the backward paths for *PartB*. Change the *Entity Type* property for the second Source to *PartB*. At this point your model should appear as follows:



Our next step will be to create sequence tables for *PartA* and *PartB* that define their travel sequence through the system. To do this click on the Data window tab just under the ribbons. The Data window is used to define various types of data that can be used with your model and we will discuss this functionality in detail in Chapter 5. For now we will focus on creating Sequence Tables. In the tables section click on Add Sequence Table and rename the table *PartASeq*. Repeat this same step and rename this second table *PartBSeq*. Next drag the *PartBSeq* tab and drop it on the right window target so that we can see both tables simultaneously (you can alternatively right click on either table tab and select New Vertical Tab Group. Now enter the sequence *Input@Server1, Input@Server2, Input@Server3, Input@Sink1* for *PartASeq*, and enter *Input@Server3, Input@Server2, Input@Server1, Input@Sink* for *PartBSeq*. At this point your table data should appear as follows:



PartASeq

Sequence
Input@Server1
Input@Server2
Input@Server3
Input@Sink1

PartBSeq

Sequence
Input@Server3
Input@Server2
Input@Server1
Input@Sink1

Properties: PartBSeq (Table)

General	
Name	PartBSeq
Description	

General

If you click on the column labeled Sequence in *PartASeq* the Property window will display properties for the sequence. The property *Accepts Any Node* is by default set to *True* and allows for any node in the model to be specified with its fully qualified name (e.g. *Input@Server1*). You can optionally change this property to *False* then only fixed objects may be specified using abbreviated names with the input node name and @ sign omitted for all fixed objects with a single input node (e.g. a Server). For example the sequence for *ParASeq* could be specified as *Server1, Server2, Server3, Sink1*. This is particularly convenient when importing routings from external data sources (discussed in Chapter 5).

Now that we have defined our routing sequences we are ready to use them in our model. Click on the Facility tab to bring the facility window to the front. Click on the *PartA* entity and set its Initial Sequence property to *PartASeq*, and click on the *PartB* entity and set its Initial Sequence property to *PartBSeq*. Now click on the output nodes for the two Sources and three Servers and specify *the Entity Destination Type* as *By Sequence* (you can do this by group selecting with Control-Click). Clicking on the Run button in the Run ribbon will now start the model executing.

Whenever an entity is routed from a node with the *By Sequence* option, it automatically bumps its index into the sequence. Hence each part type will be sent to the next destination that is listed in the sequence table that it is following. As we will see later you can also change the sequence table that an entity is following during the simulation (e.g. after failing inspection a part may be assigned to follow a rework sequence).

Summary

This chapter has focused on the concepts related to controlling the flow of entities between objects across a network of links. These basic concepts can be used to model a wide range of both static and dynamic entity flows. In the next chapter we will focus on the logic that executes once an entity enters the objects in the Standard Library.

Chapter 3: Standard Library

Overview

In this chapter we will describe in more detail the objects in the Standard Library. This library is designed to be a generic modeling library with a broad spectrum of application. So far we have already made some use of the Source, Server, Sink, and Path objects from this library in the simple models that we have built so far. We will describe these in more detail, as well as the library objects that we have yet to use. However before describing these individual objects we will first introduce some general modeling concepts that are employed by these objects.

Preliminary Concepts

As noted in Chapter 1 the objects in Simio have both a general behavior and specific behavior. The general behavior is defined by one of five basic classes: fixed, node, link, entity, and transporter. A fixed object models some general activities that take place at a specific location and are triggered by the arrival an entity. A node object models the starting and/or ending point of one or more links, and also defines the entry and exit point for a fixed object. Hence most fixed objects have associated node objects that provide input and output to the object. A link object models the pathway between two nodes. An entity object can be dynamically created and destroyed, may move through free space or over a network of links, and move into and out of fixed objects. Finally a transporter is a sub-class of entity that can also pickup, carry, and drop-off other entities. Although the object class defines the general behavior of each object, the specific behavior is defined by an internal model for the object definition. Hence each of these classes can have many different object definitions, each with different specific behaviors for the corresponding objects that are placed in a model. Hence the Standard Library is just one of many possible libraries that can be used for modeling. The ability to create custom libraries is a very powerful feature of Simio.

There are number of important concepts that are employed in designing and building object definitions. We will explore this topic in more detail in Chapter 6 where we explore the design and building of custom objects. For now it is important to understand some basic concepts related to **stations** and **resources**.

Many of the objects in the Standard Library make use of the concept of a station. A station is a construct in Simio that is used to model a constrained location within an object. Entities can transfer from station to station within an object. Only one entity can transfer into a station at a time, and this transfer can require time to execute. A station can also have a fixed capacity that will limit the number of entities that are in process at the station. Whenever a station is at its capacity the station will block any attempts by other entities to transfer into that station.

As an illustration the Server object employs three stations named *InputBuffer*, *Processing*, and *OutputBuffer*. An entity first enters the Server at the *InputBuffer* station, then moves to the *Processing* station, and then finally moves to the *OutputBuffer* station. Each station in Simio has two internal queues named the *EntryQueue* and *Contents*. The queue named *EntryQueue* holds entities that are waiting to transfer into the station, and the *Contents* queue holds the entities that are currently located inside the station.   Hence the expression *Server1.Processing.Contents* denotes the queue of entities in the *Processing* station at Server1, and the expression *Server1.Processing.EntryQueue* denotes the queue of entities waiting to transfer into the *Processing* station. Likewise the Vehicle object employs a station named *RideStation* to hold the entities that are currently riding on the Vehicle.

Many of the objects in the Standard Library also declare themselves as a resource. If an object declares itself as a resource, then it has a changeable capacity that can be seized and released by other objects. The object also as a queue named *AllocationQueue* that holds a prioritized list of other objects that are waiting to seize it. When capacity becomes available it can be allocated statically based on this prioritized list, or dynamically based on user-customizable rules. This latter feature makes for very flexible resource allocation. As we will see later, objects can implement logic to either accept or reject a seize attempt by another object. When an object is seized a visit request can also be made to have the seized object travel to a specific location. In this case the request is placed in the *VisitRequestQueue* for the object and the object can then decide when and if to visit the requesting object. Hence seizing and moving a resource object requires cooperation between the seizing object (e.g. a workstation) and the object being seized/moved (e.g. an operator). These features will be described in more detail in Chapter 5.

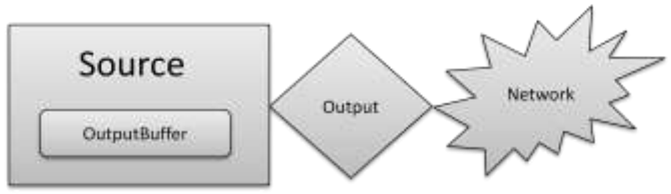
Within the Standard Library all of the fixed objects, nodes, and the Vehicle and Worker are declared as resources.   You can also add entities and transporters to your project and declare them as resources. The Standard Library also contains a fixed object named Resource that is specifically provided for use as a stationary (non-moving) resource object for seizing and releasing.

All of the objects in the Standard Library support the concept of Add-On processes. An Add-On process is user-defined process that may be inserted into the object logic at a number of predefined points. As a result you can actually customize the behavior of these objects without having to create new objects. We will discuss this functionality in detail in Chapter 4. Most of the Standard Library objects also support the concept of entity state assignments upon arrival to and/or departure from the object.

Source and Sink

As we have already seen in our previous examples, the Source and Sink are fixed objects that are used to dynamically create and destroy entities. We will now exam each of these objects in more detail.

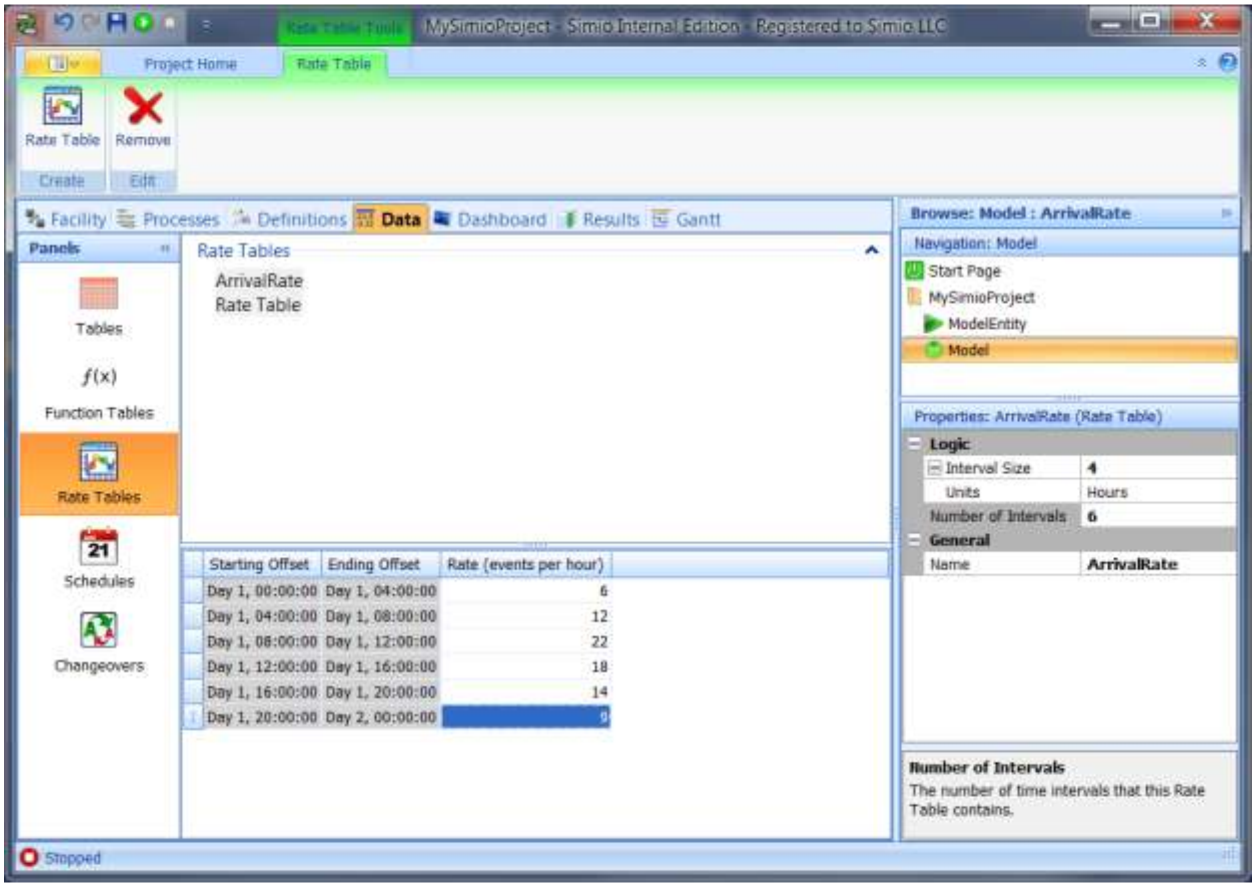
The Source is comprised of the main Source object plus the associated output node (type TransferNode) named *Output*. You independently select and edit both the main Source object and the associated output node. The main Source object has an *OutputBuffer* station that holds entities that are waiting to exit the source through the associated output node. Once an entity successfully transfers into the network through the output node it then departs the *OutputBuffer* station that is owned by the Source. The relationship between the OutputBuffer station that is owned by the Source, and the associated Output node is shown below:



By default the Source includes an attached animated queue that displays the entities in its *OutputBuffer.Contents* queue. Note that an animated queue can be added as either a detached queue or an attached Queue. An attached queue is one that is defined in the context of and moves with the associated object, whereas a detached queue is free-floating and defined in the context of the parent model. Hence if you drag the Source object the attached animated *OutputBuffer.Contents* queue will move with it. If you place a Source, click on the output queue, and press the delete key you will delete the animated queue. Note that this does not in any way impact the logic for the Source – the logical station queue still exists – its contents are simply no longer being animated. To re-attach an animation queue to the Source click on the Source object in the facility, click on the down arrow on the Queue icon, and select *OutputBuffer.Contents* from the drop list. To add a detached queue select the Animation ribbon and click on the Detached Queue icon. In this case you must enter the Queue State property to animate using the fully qualified name (e.g. *Server1.OutputBuffer.Contents*).

The arrival logic properties for the main Source object include the *Entity Type, Arrival Mode,* and *Entities Per Arrival*, along with additional properties that switch in and out based on the *Arrival Mode*. The *Entity Type* specifies the type of Entities created by the Source. The *Entities Per Arrival* property specifies how many entities are to be created for each arrival event at the source.

The *Arrival Mode* property governs the pattern of arrivals. The default mode is specified as *Interarrival Time*, which switches in properties for specifying the *Time Offset* for the first arrival, and *Interarrival Time* for subsequent arrivals. The mode *Time Varying Arrival Rate* is used to model a non-homogenous Poisson arrival process in which the time varies according to a Rate Table that is defined in the Data window. To create a Rate Table select the Data window, click on Rate Tables in the selection panel on the left, and then click on Rate Table in the ribbon, which then creates a default Rate Table. A Rate Table is a set of equal size intervals that specify the mean arrival rate during that interval. Note that the arrival process is random and so that actual number of arrivals during a given interval may be more or less than this expected value. You can specify the number of intervals as well as the interval size. The Rate Table will automatically repeat once it reaches the end of the last interval. The following shows a Rate Table with six intervals, each four hours long. Once this Rate Table is defined, it can then be referenced with the *Time Varying Arrival Rate* mode.



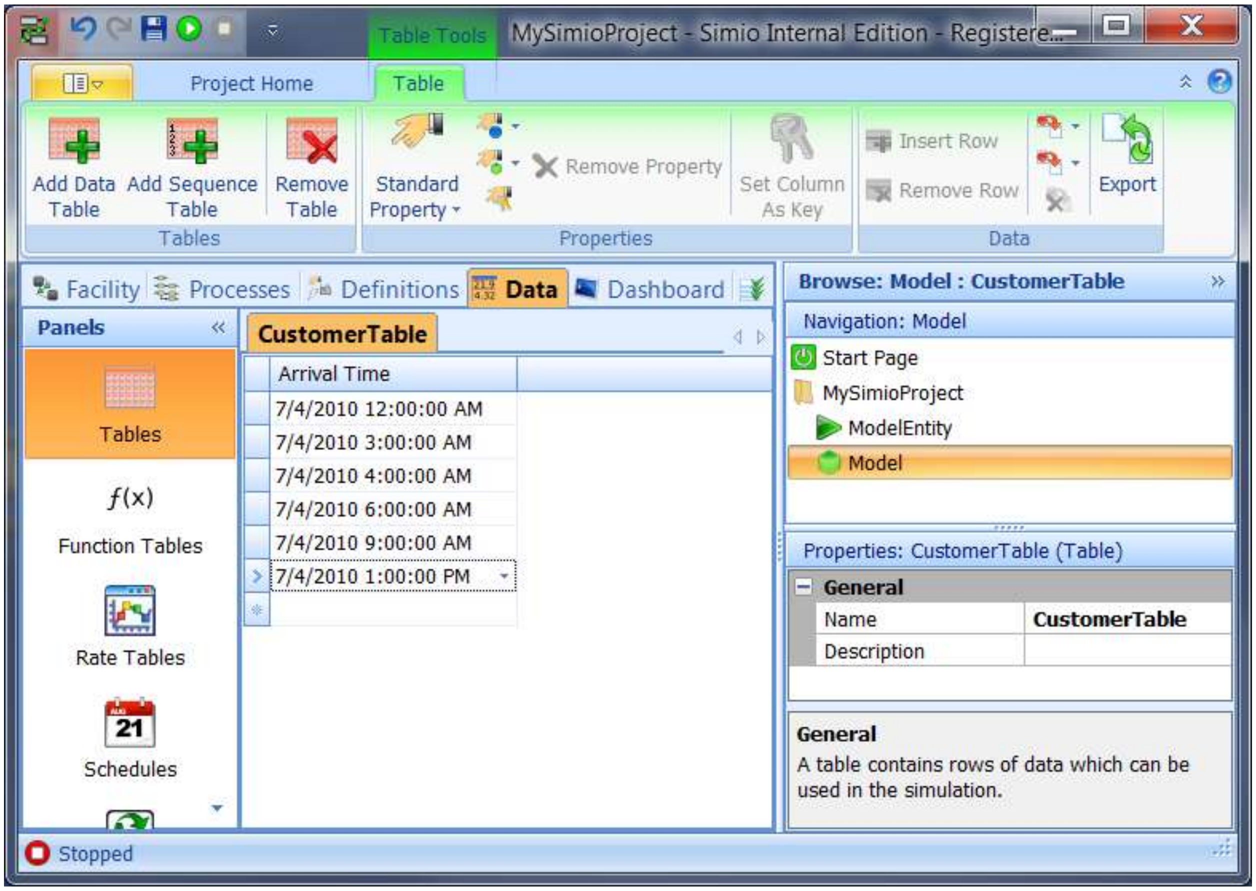
Starting Offset	Ending Offset	Rate (events per hour)
Day 1, 00:00:00	Day 1, 04:00:00	6
Day 1, 04:00:00	Day 1, 08:00:00	12
Day 1, 08:00:00	Day 1, 12:00:00	22
Day 1, 12:00:00	Day 1, 16:00:00	18
Day 1, 16:00:00	Day 1, 20:00:00	14
Day 1, 20:00:00	Day 2, 00:00:00	9

Properties: ArrivalRate (Rate Table)

Logic	
Interval Size	4
Units	Hours
Number of Intervals	6
General	
Name	ArrivalRate

Number of Intervals
The number of time intervals that this Rate Table contains.

The mode *Arrival Table* is used to generate a specific set of arrivals based on arrival times specified in a table that is defined in the Data window. To use this mode we must first create a table that contains a list of arrival times that entities enter the system. To create an Arrival Table select the Data window, click on Tables in the selection panel on the left, and then click on Add Data Table in the ribbon, which then creates a default Data Table. We will rename this table by changing the *Name* property in the Property window to *CustomerTable*. We will now click on the down arrow for Standard Property and select a Date Time property to add to the table, and rename this property ArrivalTime. We can enter arrival time values into this table as shown below:



CustomerTable

Arrival Time
7/4/2010 12:00:00 AM
7/4/2010 3:00:00 AM
7/4/2010 4:00:00 AM
7/4/2010 6:00:00 AM
7/4/2010 9:00:00 AM
7/4/2010 1:00:00 PM

General	
Name	CustomerTable
Description	

General
A table contains rows of data which can be used in the simulation.

Once we have defined are arrival table we can then reference this table and arrival time column using the Arrival Table mode for the Source object. In this example the Arrival Table is specified as *CustomerTable.ArrivalTime*. The Source will then generate arrivals at the times specified in this table. We will discuss the creation and use of Data Tables in much greater detail in Chapter 5 where we describe the use of tables for building data driven models.

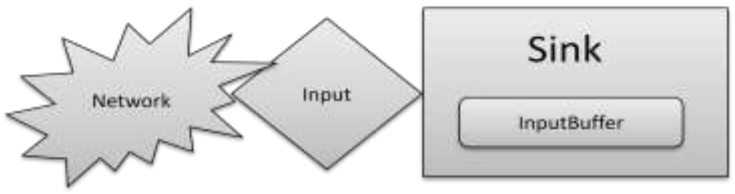
The *On Event* mode is used to create a new entity every time an event fires, and switches in a property for specifying the *Event Name* for the triggering event. Many of the objects in the Standard Library fire events at selected times, and we can use these to cause the creation of a new entity. For example specifying the triggering event as *Input@Sink1.Entered* would cause the Source to create a new entity each time an entity entered the input node at Sink1. When selecting this mode you can also specify the property *Initial Number Entities* to create an initial set of entities in addition to those that are created for arrivals that are triggered by each event firing.

Source Stopping Conditions – Note that the Source object also provides a 'Stopping Conditions' category of properties that allows you to easily stop arrivals generated by the source using one or more of the following conditions:

- After a specified Maximum Arrivals has occurred.
- After a specified Maximum Time has elapsed.

- After a specified event has occurred.

The Sink object is the counterpart to the Source object – it destroys arriving entities and removes them from the system. The Sink is comprised of the main Sink object plus the associated input node (type BasicNode) named *Input*. Only one entity at a time can be processed by the Sink. The Sink has InputBuffer station that holds the entity being processed for the specified *TransferIn Time*. Entities are transferred from the network thru the *Input* node and into the *InputBuffer* station. The relationship between the *Input* node and *InputBuffer* station is shown below:

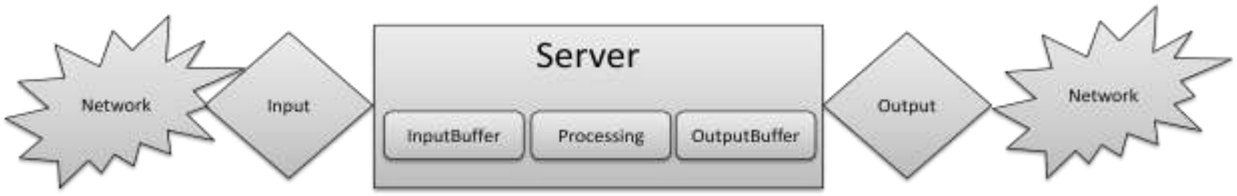


The Sink comes with an attached queue for animating the entity in the *InputBuffer* station. The Sink automatically records the average time in system for entities that are destroyed by the Sink.

Server

We have used the Server object in several of our previous examples to model a constrained service operation. The main Server object has two attached objects: an input node (type BasicNode) and an output node (type TransferNode).

As noted earlier the main Server is modeled with three stations: *InputBuffer, Processing*, and *OutputBuffer*. An arriving entity typically enters from the network through the *Input* node to the Server's *InputBuffer*, proceeds through *Processing*, and then waits in the *OutputBuffer* to move through the output node and into the network. Note that the network may be blocking an attempt to transfer out through the *Output* node (e.g. a path with no passing may be fully backed up and have no available space). In a similar way when the Server is full it may be blocking the network on the input side.

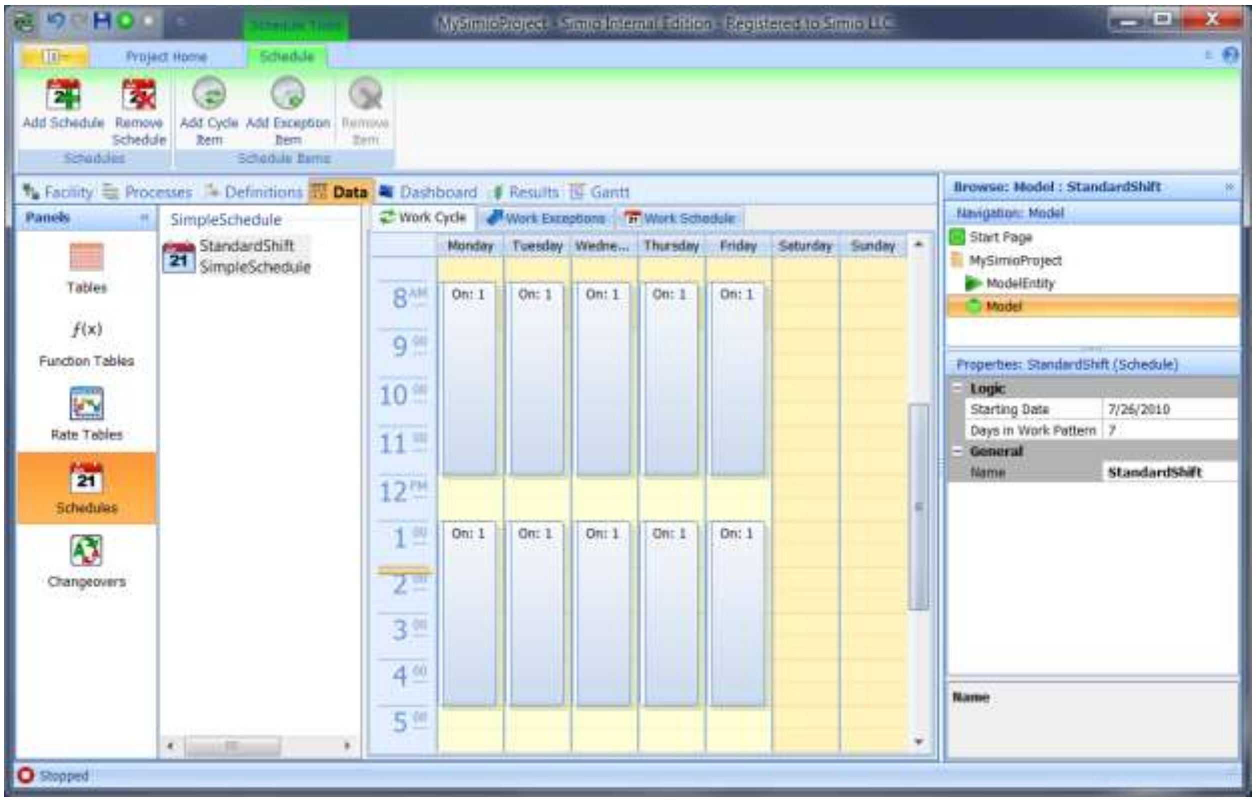


Both the *InputBuffer* and the *OutputBuffer* stations can have their capacities set to zero which causes them to be removed from the logic. Hence if the *OutputBuffer* capacity is specified as zero the entity completing *Processing* will wait in *Processing* to move through the output node and into the network. Likewise if the *InputBuffer* capacity is set to zero, then entities that are entering from the network through the input node must proceed directly to the Processing station of the Server. If the Processing station is at its capacity it will block entities attempting to enter the Server.

Whenever processing capacity becomes available the next entity to be processed is selected from the *InputBuffer*. The *InputBuffer* is ranked based on the Ranking Rule property, that can be specified as *First In First Out, Last In First Out, Smallest Value First, or Largest Value First*. In the last two cases you specify an expression on which the ranking is based – e.g. you could rank the queue based on processing time or due date. If no *Dynamic Selection Rule* is specified then the first entity in the statically ranked queue is selected for processing. However if a *Dynamic Selection Rule* is specified, then all entities in the queue are examined and considered for selection based on the specified rule. These rules include *Smallest Value First* and *Largest Value First*, which from their name seem like similar options to the simple *Ranking Rule*. However this dynamic rule is actually more flexible and powerful (although slower to execute) because it re-evaluates the expression for each entity at the time each decision is made. For example an expression that has a term that computes if the entity is tardy (by comparing its due date to the current time) would correctly use the current time when making this decision, and not the arrival time to the queue. The three campaign rules are used to make selections in an increasing or decreasing order based on a specified expression. For example, a Server modeling a painting operation may move from light to dark colors, and then start over with the lightest color once no darker colors remain.

The *TransferIn Time* property on the Server specifies the time required for an entity to transfer into the Server object. Only one entity may transfer at a time, and processing of the entity may not start until this transfer is completed. The *Processing Time* property specifies the time required to process the entity at the Processing station.

The Server object can be used to model either a single server or a single processing center with multiple identical servers, depending upon the capacity specified for the Processing station. The Processing station is governed by a *Capacity Type* that is specified as either a *Fixed* capacity, or based on a *WorkSchedule.* To specify a capacity based on a *WorkSchedule* first create a schedule by clicking on the Data window, selecting the Schedules panel on the left, and then clicking on Add Schedule in the Schedule ribbon. A schedule is made up of two parts: a repeating work cycle with superimposed work exceptions. A work cycle defines a repeating work pattern that defaults to seven days, but can be set to any arbitrary number of days. You then define the cycle items that define on and off shift periods within the repeating work cycle. By default the schedule is off shift, so normally you only define the on shift periods. You can either add cycle items to the work cycle from the ribbon, or you can right click at any location on the work schedule to add a new item. You can drag any cycle item to a new location, stretch its length. You can copy a cycle item by clicking the day where you are copying to, then hold down the CTRL key and select the item that is to be copied, and drag it to the day where it should be copied. You add and edit work exceptions in a similar way. A work exception is use to override the underlying work schedule – e.g. to specify holidays or overtime. The following shows a simple seven-day work schedule named *StandardShift* that defines a capacity of one from 8-12 and 1-5 on Monday thru Friday. Note that a single work schedule can be referenced by multiple servers.



Properties: StandardShift (Schedule)

Logic	
Starting Date	7/26/2010
Days in Work Pattern	7
General	
Name	StandardShift

When modeling multiple servers there is always the option to model each server as a separate Server object in Simio, or use a single Server object with a capacity set to the number of servers. The latter is far simpler and will produce identical results as long as all the servers have the same performance characteristics, and waiting customers always go to an available server.

The Server also provides options for failures that halt processing by the Server during the failure. The failures supported include *Calendar Time Based, Processing Count Based,* and *Event Count Based*. In all three cases the failure duration is specified by the *Time To Repair* property.

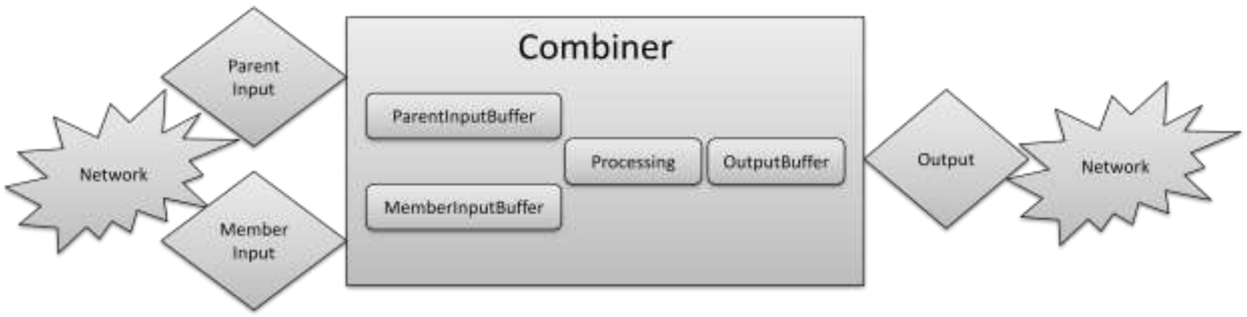
By default the Server object has animated queues for the *InputBuffer*, *Processing*, and *OutputBuffer*. Again these are animation only constructs and have no impact on the logic of the Server. It may be necessary to lengthen the animation queue to see all the entities that are actually in the station.

Combiner and Separator

The Combiner and Separator are similar to the Server in many ways, however provide additional functionality to combine several entities together, and then to separate them or to make copies of a single entity.

The Combiner is used to model a process that matches multiple entities, groups those entities into a batch, and then attaches those batched members to a parent entity. For example, if we have parts being placed on a palette, the batched members would be the parts, and the parent entity would be the palette. The individual batched entities can later be split out using the Separate.

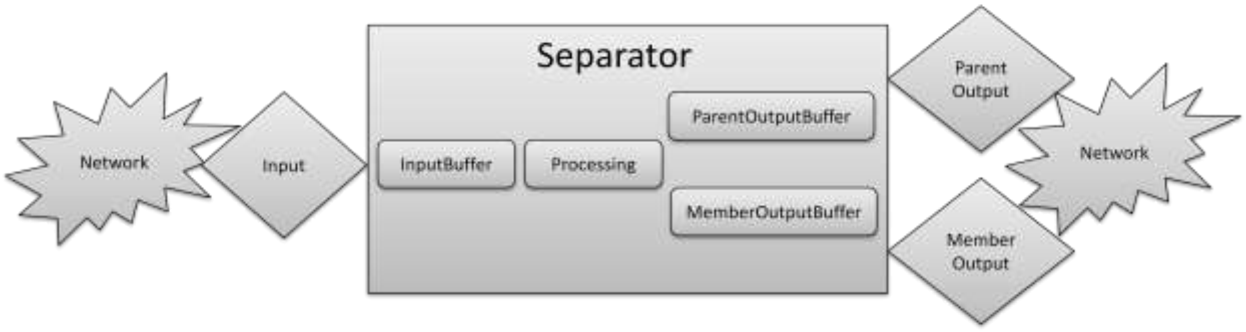
The Combiner is comprised of a main object plus three associated node objects, including an input node named *ParentInput* for the parent entities, an input node named *MemberInput* for the member entities, and an output node named *Output* for the batched entities. The main Combiner object has four stations: *ParentInputBuffer*, *MemberInputBuffer*, *Processing*, and *OutputBuffer*. Arriving parent entities transfer from the network thru the *ParentInput* node to the *ParentInputBuffer* station, and arriving member entities transfer from the network thru the *MemberInput* node to the *MemberInputBuffer* station. The entities are then formed into batches in the *Processing* station, and then wait in the *OutputBuffer* station to depart into the network through the *Output* node. The relationship between these node objects and the associated stations is shown below:



The properties for the Combiner include the *Batch Quantity* and *Matching Rule*. A batch is formed by selecting the number of members specified by the *Batch Quantity* from the member queue, and attaching them as a batch to a single parent entity selected from the parent queue. The *Matching Rule* options include *Any Entity, Match Members,* and *Match Members and Parent*. In the case of *Any Entity* then entities are selected in the order that they are ranked in the queue. In the case of *Match Members* then a batch can only be formed if the member entities all have the same value for the *Member Match Expression*. In the case of *Match Members and Parent* then a batch can only be formed if the member entities all have the same value for the *Member Match Expression*, and there is a waiting parent entity with the same value for the *Parent Match Expression*. The batched members are carried by the parent entity in a queue named *BatchMembers* which can be animated on the parent entity symbol.

The processing capacity and reliability for the Combiner are specified similar to the Server. A good way to think about the Combiner is that it's a special purpose Server with two input nodes and special processing logic for batching.

The Separator is used to model a process that separates batched members from a parent entity, or makes copies of an entity. Essentially the Separator is a mirror image of the Combiner. The Separator is comprised of a main object plus three associated node objects, including an input node named *Input* for the arriving parent entities, an output node named *ParentOutput* for the departing parent entities, and an output node named *MemberOutput* for the departing member entities. The main Separator object has four stations: *InputBuffer*, *Processing*, *ParentOutputBuffer,* and *MemberOutputBuffer*. Arriving parent entities transfer from the network thru the *Input* node to the *InputBuffer* station. The entities are then split apart or copied in the *Processing* station, and then the parent entities wait in the *ParentOutputBuffer* station to depart into the network through the *ParentOutput* node, and the member entities wait in the *MemberOutputBuffer* station to depart to the network thru the *MemberOutput* node. The relationship between these node objects and the associated stations is shown below:

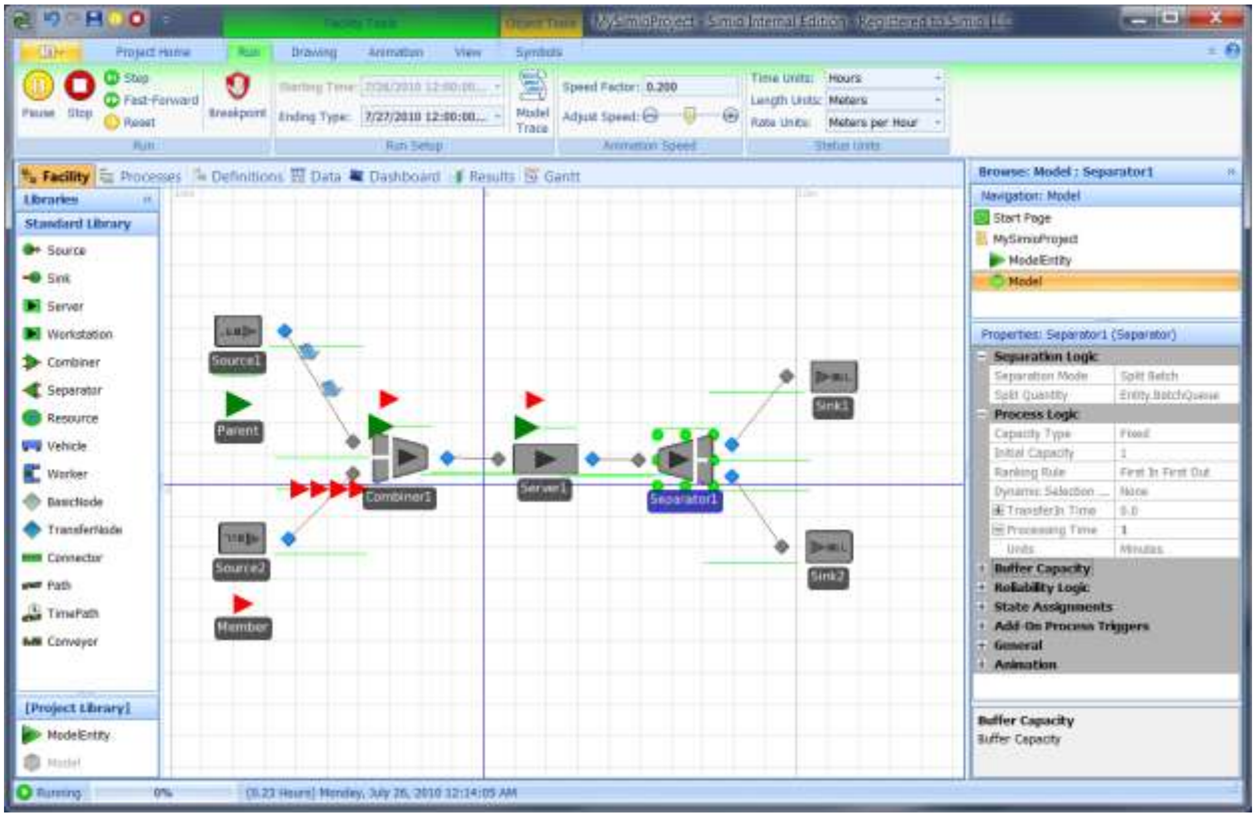


The processing logic for the Separator is controlled by the *Separation Mode* that can be specified as either *Split Batch* or *Make Copies*. In the case of the *Split Batch* option, entities that are carried by the parent entity in its *BatchMembers* queue are split off and transferred to the *MemberOutputBuffer* where they wait to depart the Separator. The parent entity is then transferred to the ParentOutputBuffer when it waits to depart the Separator. The number of entities that are split off is specified by the Split Quantity property which defaults to the total number of members in the parent entity's BatchMembers queue. In the case of the *Make Copies* option members are created by cloning the parent entity, with the number of newly created members specified by the *Copy Quantity*.

Example: Combine then Separate

In this example we will model the arrival of two different entity types that have independent arrival processes and are combined together, processed as a combined batch, and then un-batched before departing the systems. Each entity type arrives randomly with an exponential time between arrivals with a mean of 1 minute. The time to batch two entities is a constant .5 minutes, and the time required to un-batch the entities is a constant 1 minute. The processing time for the combined batch has a triangular distribution with a minimum of .5, mode of .8, and maximum of 1.2 minutes.

Begin by opening Simio and selecting a new model Project.   Now place two entities from the Project Library and rename them *Parent* and *Member*. Resize the *Parent* entity to make it larger. Select the *Parent* entity and click on the down arrow below the Queue icon on the Symbols ribbon and select *BatchMembers*. Using the cross hair cursor draw the attached queue just above the *Parent* entity (make sure it's long enough to contain at least one *Member* entity) and then terminate queue drawing with a right-click. Note that this attached queue will animate any member entities that are held in the *BatchMembers* of the Parent entity. Now select the *Member* entity, select the color red, and click on the *Member* entity again to apply the color. Drag out two Sources, a Combiner, a Server, a Separator, and two Sinks from the Standard Library. Now connect the objects with Paths as shown below:



Properties: Separator1 (Separator)

Separation Logic	
Separation Mode	Split Batch
Split Quantity	Entity.BatchQueue
Process Logic	
Capacity Type	Fixed
Initial Capacity	1
Ranking Rule	First In First Out
Dynamic Selection ...	None
TransferIn Time	0.0
Processing Time	1
Units	Minutes
Buffer Capacity	
Reliability Logic	
State Assignments	
Add-On Process Triggers	
General	
Animation	

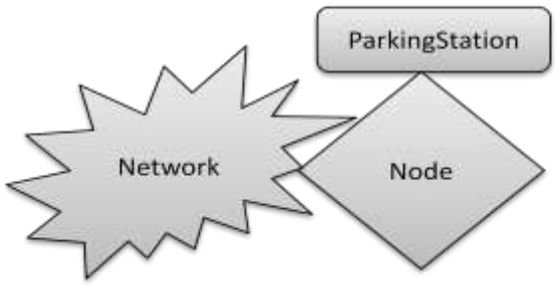
Change the *Interarrival Time* for both Sources to *Random.Exponential(1)*, and change the *Entity Type* for Source2 to *Member*. Set the *Processing Time* properties for the Combiner, Server, and Separator to *.5, Random.Triangular(.5, .8, 1.2),* and *1* minute respectively. Now run the model to watch the batching and un-batching process.

Basic Node and Transfer Node

The Standard Library contains two different object definitions of type node. The Properties for these nodes were described in detail in Chapter 2. The BasicNode models a simple capacitated intersection with both *Shortest Path* and *By Link Weight* routing logic. The TransferNode provides additional functionality to support setting/changing the entity destination as well incorporating transport logic to support riding on transporters. We will discuss this option in more detail later in this chapter.

Within the Standard Library the BasicNode is used as an associated object on the input side of a fixed object, and the TransferNode is used as an associated object on the output side of a fixed object. Although these node objects are mostly used as associated objects with other fixed objects, these can be also be free-standing objects that are used to model intersections and even in-line processing locations in a network of links and nodes.

Nodes have a parking station named *ParkingStation* where entities/transporters can pull into and out off at the node location. A parking station allows entities to be associated with a node in the network, but be removed from the crossing area of the node so that other entities can pass through without constraint.



The entities in the parking station at a node can be animated by clicking on the node, clicking on the down arrow on the Queue icon in the Appearance ribbon, and adding an animated queue to display the entities in ParkingStation.Contents.

Connector, TimePath, and Path

Three commonly used links in Simio include the Connector, TimePath, and Path. The Connector is used to transfer an entity between two nodes in zero time. The only property on the Connector is the *Selection Weight* used for routing *By Link Weight*. The TimePath is used to transfer an entity between two nodes with a specified *Travel Time*. The TimePath can also have a limited *Travel Capacity*, and an *Entry Ranking Rule* for controlling the order in which entities enter the TimePath.

The Path is used to model a pathway in which each entity on the Path can move at its own assigned speed. As a result the Path has an *Allow Passing* property that governs what happens when a fast moving entity closes in on a slower moving entity. The Path also has a *Speed Limit* property that will limit the speed of any entities moving thru the Path. By default the travel of the path is based on the geometric length of the pathway that is drawn in the facility. If you graphically increase the length of the physical path then you also increase the logical travel distance. You can also set the *Drawn To Scale* property to false which allows you to specify the *Logical Length* of the Path.

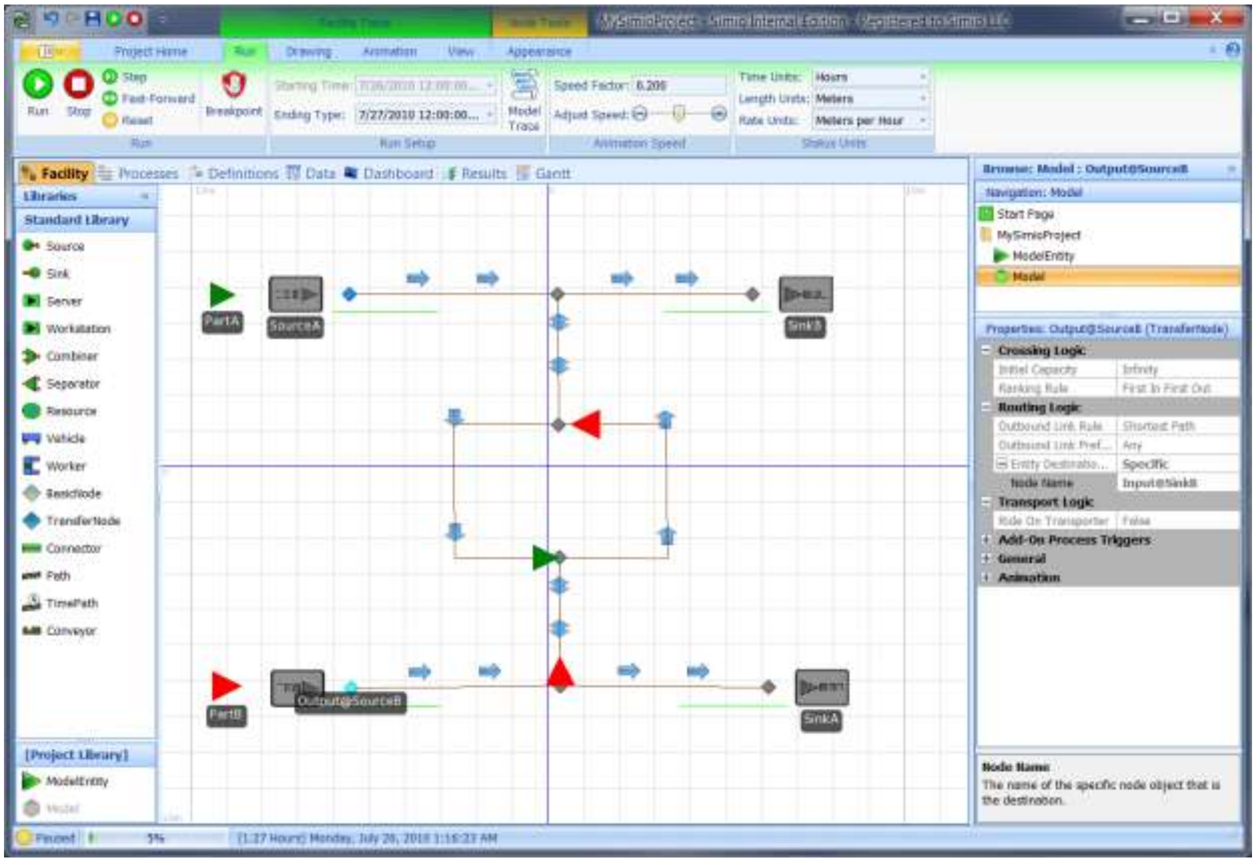
Both the TimePath and the Path have a *Type* property that can be specified as *Unidirectional* or *Bidirectional*. If you set this property to Bidirectional then entities can travel through the link in either direction. However with *Bidirectional* links traffic can only travel in one direction at a time. For example if a *Bidirectional* link is drawn between nodes A and B, then any traffic traveling from B to A must wait for all traffic traveling in the link from A to B to complete their travel and exit the link.

With *Bidirectional* links it is very easy to create situations where the traffic will deadlock. The link network should be designed in such a way that deadlocks are avoided.

Example: Bidirectional Paths

In this example we have two different parts that travel in opposite directions through a bidirectional network with sides provided to avoid deadlock. Our example model is shown below. *PartA* entities enter at *SourceA* and have their destination set on the Output node for *SourceA* to *SinkA*. *PartB* entities enter at *SourceB* and have their destination set on the Output node for *SourceB* to *SinkB*. We have placed four free-standing BasicNodes vertically aligned in the center of the facility to represent intermediate intersections. We have drawn Paths between nodes as shown and set *Allow Passing* to *False* on all Paths. We have also set the two vertical Paths in the center of the facility to *Bidirectional*.

Note that entities will automatically wait for oncoming traffic to clear before entering a *Bidirectional* link. Note also the crucial role played by the two side pathways in the center of the facility to buffer against deadlocks with the two *Bidirectional* paths. Without these side pathways traffic would deadlock at the intersection of the two *Bidirectional* paths.



Starting Time: 7/26/2010 12:00:00...
Ending Type: 7/27/2010 12:00:00...
Speed Factor: 6.208
Time Units: Hours
Length Units: Meters
Rate Units: Meters per Hour

Properties: Output@SourceB (TransferNode)

Crossing Logic	
Initial Capacity	Infinity
Ranking Rule	First In First Out
Routing Logic	
Outbound Link Rule	Shortest Path
Outbound Link Pref...	Any
Entity Destinatio...	Specific
Node Name	Input@SinkB
Transport Logic	
Ride On Transporter	False
Add-On Process Triggers	
General	
Animation	

Node Name
The name of the specific node object that is the destination.

5% (1.27 Hours) Monday, July 26, 2010 1:16:23 AM

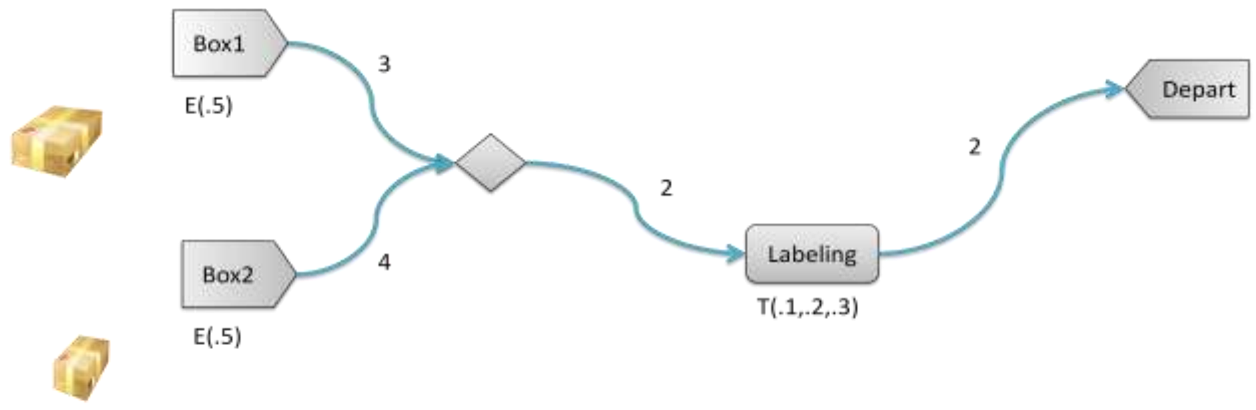
Conveyors

The fourth type of link provided in the Standard Library is the Conveyor. In contrast to the Path where the entities can move independently at different speeds across the link, with a Conveyor the entity movement is governed by the current speed of the Conveyor. Entities merge onto and consume space on the conveyor and rely on the conveyor to provide their movement. The *Accumulating* property determines what happens with the Conveyor when an entity reaches the end of the link and is blocked from continuing. If *Accumulating* is *True* then the conveyor does not stop moving and the moving Conveyor is assumed to slip relative to the stopped entity. In this case trailing entities will accumulate behind the stopped entity. If *Accumulating* is *False* then the Conveyor is also stopped. The Conveyor will start moving again at the *Desired Speed* once the blockage is removed.

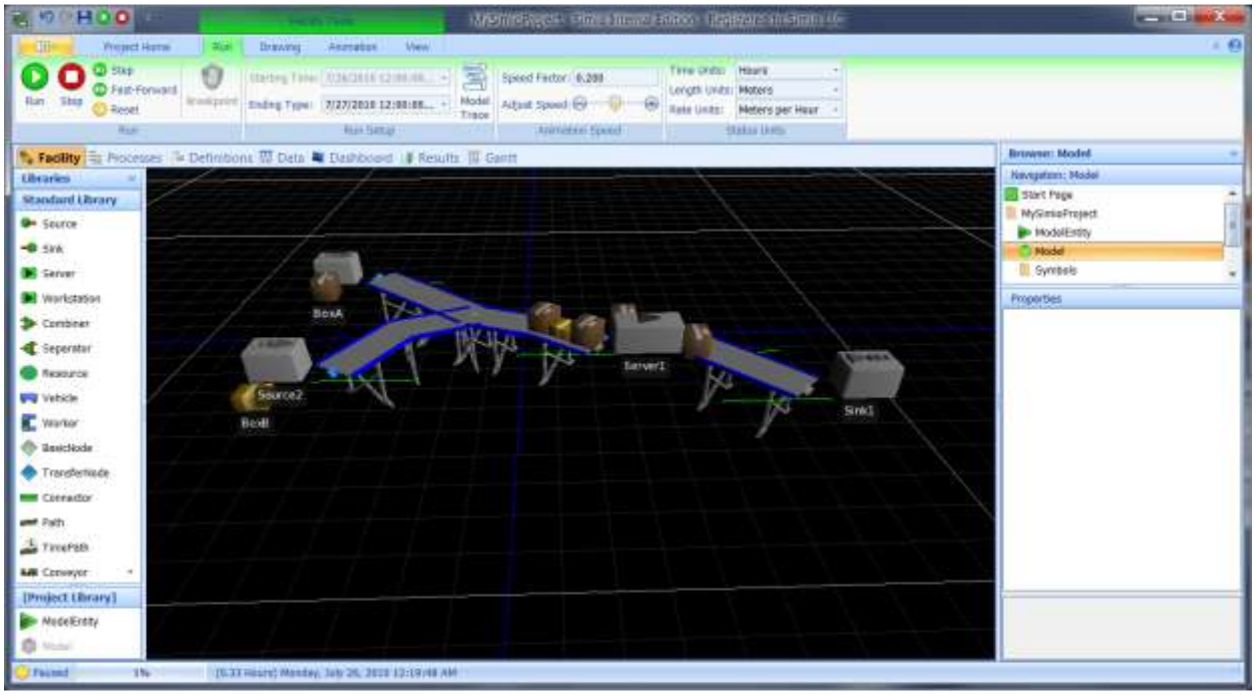
By default entities can merge onto the Conveyor at any location. Some conveyor devices (e.g. bucket conveyors, ski lifts, etc.) only allow entities at fixed locations along the device. This can be modeled by changing the *Entity Alignment* property from *Any Location* to *Cell Location*, and then specifying the Number of Cells on the Conveyor.

Example: Merging Conveyors

In this example we have two different types of boxes arriving along separate accumulating conveyors to a merge point, where they continue along a third accumulating conveyor to a server. Following a labeling operation they continue on a fourth accumulating conveyor to their departure point from the system. Both box types arrive with an interarrival time is that is exponentially distributed with a mean of .5 minutes. The service time has a triangular distribution with a minimum of .1, mode of .2, and maximum of .3 minutes. The conveyor supplying Box1 moves at 3 meters per second, and the conveyor supplying Box2 moves at 4 meters per second, and these merge onto a conveyor moving at 2 meters per second. The boxes depart from the server on a conveyor moving at 2 meters per second. The facility layout is shown below:



Begin by opening Simio and selecting a new model Project. Place two Sources, a Basic Node, Server, and Sink and connect them with conveyors. Now place two entities from the Project Library and rename them *BoxA* and *BoxB*, and select new symbols for the entities from the Project Symbols on the Symbols ribbon. Edit the parameters for the *Interarrival Time* on *Source1* and *Source2*, and change the *Entity Type* for *Source2* to *BoxB*. Set the InputBuffer capacity to 0 for *Server1* (which causes entities to accumulate on the conveyor at the input to the Server), and change the conveyor speeds coming out of the Sources to 3 and 4, respectively. Click on each conveyor and apply the Path Decorator for the conveyor. The model is now ready to run and shown below:



Vehicle

The Standard Library has a transporter definition named Vehicle. The Vehicle may be used to transport objects between node locations in the network. A transporter has a single station named RideStation where entities are held during transport. The Vehicle can be used to model devices that follow a fixed route (e.g. a bus, train, etc.), or respond to dynamic requests for pickups (e.g. taxi, AGV, etc.). To use the Vehicle you drag a Vehicle object from the library and place it anywhere in the facility model. You then click on this Vehicle object to edit its properties.

The routing logic for a Vehicle is controlled by properties that specify the *Initial Node* and *Routing Type*. The *Initial Node* (also referred to as the Home node) specifies the starting location for the transporter. The *Routing Type* is used to specify if the transporter follows a *Fixed Route*, or responds to *On Demand* request for pickups and drop-offs. In the case of *Fixed Route* the sequence table name defining the *Route Sequence* is also specified. In the case of *On Demand* the *Idle Action* to take when there are no active pickups or drop-offs to perform is also specified. The options for *Idle Action* include *Go To Home* (travel to the Home node but remain on the network), *Remain In Place* (i.e. remain at current location on the network), *Park At Home* (travel to the Home node and pull into the parking area at that node), *Park At Node* (pull off the network into the parking area for the current node), and *Roam* (move randomly through the network based on link weights).

Note that when modeling with transporters it is typically desirable to add animated queues for the parking stations at each node where the transporter may park. This would include the *Initial Node* where the transporter starts, as well as any nodes where the transporter may park along the way. If you do not add these animated queues to these nodes then the transporters will show up in default parking queues whenever they are parked in the parking station.

By default, a parking area is supplied adjacent to each node. Whenever an object (such as a vehicle) parks at the node, if the Parking Queue option is enabled for the node on the Appearance ribbon, then the object will be displayed in the default parking queue. If you want to customize parking animation in any way, then you may disable this option and use the Draw Queue button in the Appearance ribbon to manually add the node's ParkingStation.Contents queue animation.

The transport logic for a Vehicle is defined by the *Ride Capacity, Load/Unload Times*, and *Task Selection Strategy*. The *Ride Capacity* specifies the maximum number of passenger entities that can be carried by the transporter. The *Load/Unload Times* specify the time required to either load or unload each passenger that gets onto/ off of the transporter. The *Task Selection Strategy* specifies a rule that the transporter uses to select its next pickup or drop-off task to perform. The strategies supported include *First In Queue, Smallest/Largest Distance,* and *Smallest/Largest Priority*.

The Initial Number In System property in the *Dynamic Objects* category on the Vehicle can be used to specify the initial number of vehicles in the system. This quantity of vehicles will be created and placed into the parking station for the *Initial Node* at the beginning of each run. Note that it is also possible to dynamically create and destroy vehicles as the model is running.

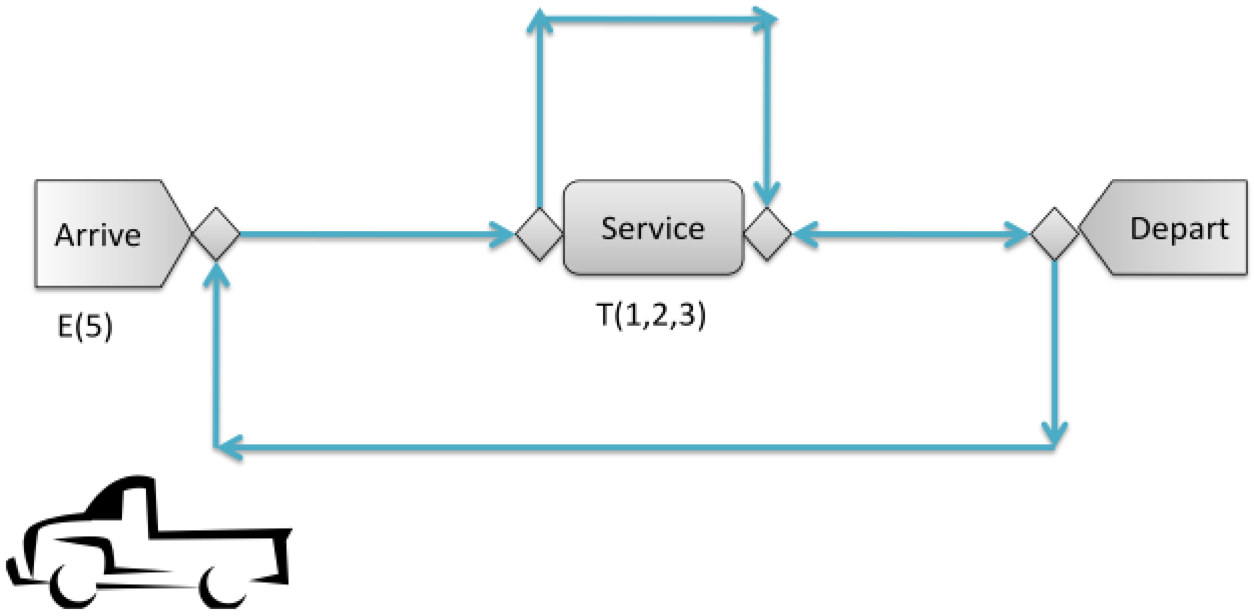
When using a transporter you must specify that entities at specific pickup points are to ride on the transporter. You can do that using the TransferNode in the Standard Library. Note that the TransferNode is used for the output node of the fixed objects (e.g. Source or Server) and this makes transporters available for access at these locations. To specify that the departing entity is to ride on a transporter (as opposed to moving through the network on its own) you set the *Ride On Transporter* property for this node to *True*, and then either specify a *Specific* transporter to use, or select the transporter *From List*. In the later case you also specify a *Reservation Method* for reserving a pickup when there is no transporter at your current location, and a *Selection Goal* and *Selection Condition* for selecting between available transporters that are currently at your location. Note that the *Reservation Method* is only employed if there is no local transporter to select. The available *Reservation Methods* include *Reserve Closest, Reserve Best, and First Available at Location*. The *Reserve Best* option applies the selection goal and condition that is used for selecting local transporters. Note that transporters will be travelling through the network performing drop-offs for its riders, and also pickups based on reservations that have been made. The *First Available at Location* waits for a transporter with available capacity to pass through this location and makes an immediate reservation with that transporter.

By default a transporter with available space will always pick up a rider, and an entity will also ride on an available transporter. As we will see in Chapter 4 you can employ an add-on process for a transporter to evaluate transport requests and refuse giving rides to specific entities. Likewise you can employ an add-on process for an entity to evaluate and reject a candidate transporter. This gives added flexibility for controlling how transporters are used within the model.

A Vehicle object with *Routing Type* specified as 'On Demand' can also seized/released by other objects for processing tasks. Each vehicle has a resource capacity of 1 and thus may be seized and used for one task at a time. When seized, a visit request to a specified node location can also be made for a Vehicle. Note that, if being used for both processing tasks as well as transport tasks, a vehicle will always prioritize seize visit requests over any new transport pickup requests. Hence the Vehicle has dual modes: as a moveable resource (e.g. similar to a worker) that is seized and released and travels from location to location in the model, and as a transporter that can pickup, carry, and drop off entities at different locations.

Example: On-Demand Pickups

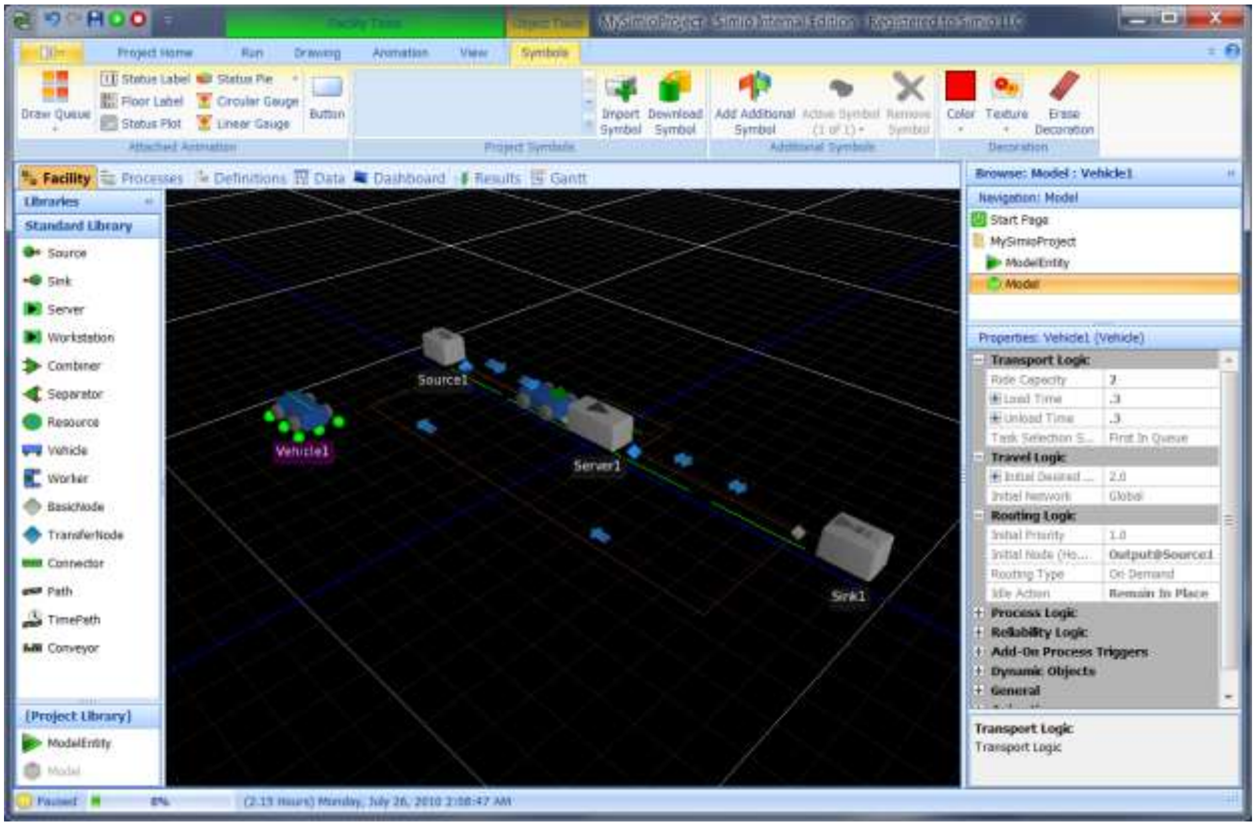
In this example passengers arrive to the system with an inter-arrival time that is exponentially distributed with a mean of 5 minutes. The passengers are picked up at the arrival point by a vehicle that can hold up to two passengers at a time, and transports them to the entry location for a service area, where their service time in minutes has a triangular distribution with a minimum of 1, mode of 2, and maximum of 3. Once passengers complete service they are then picked up by the same vehicle at the service area's exit location and carried to the departure point. The vehicle requires .3 minutes to load or unload a passenger and can travel 2 meters/second on pathway that has both unidirectional and bidirectional links as shown below.



Begin by opening Simio and selecting a new model Project. Now drag out a Source, Server, and Sink and connect them with Paths as shown, changing the *Type* for Path from the Server to the Sink to *Bidirectional*. Edit the *Interarrival Time* for the Source and *Processing Time* for the Server, and set the *InputBuffer* capacity for the Server to 0 (causing the Server to block the Vehicle on drop-offs).

Now drag an instance of the Vehicle into your model. Set the *Initial Node* for *Vehicle1* to *Output@Source1* and change the *Idle Action* to *None* (which causes the Vehicle to sit at its current location when it goes idle). Also change the *Ride Capacity* to 2 and set the *Load* and *Unload Time* to .3. Click on the output node at Source1 and add an attached animation queue for *ParkingStation.Contents*.

Finally change the *Ride On Transporter* property to true and the *Transporter Name* to *Vehicle1* on the output nodes on the Source and the Server. The model is now ready to run and is shown below:



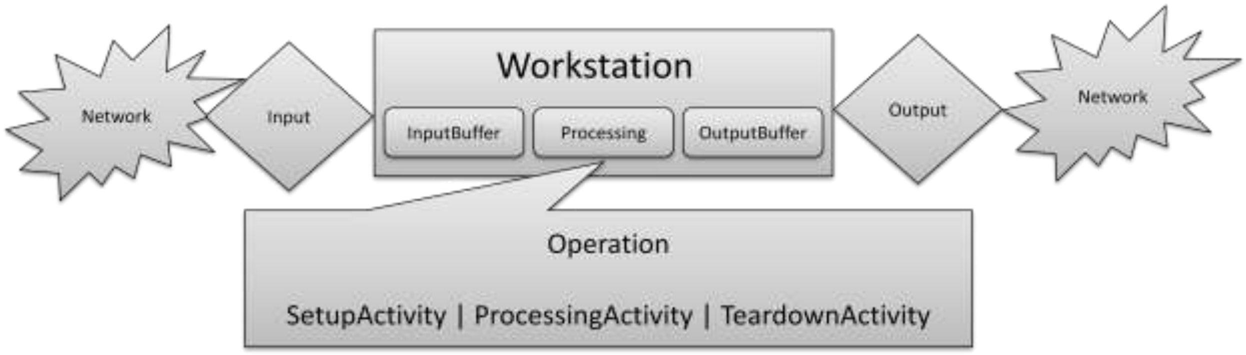
Properties: Vehicle1 (Vehicle)

Transport Logic	
Ride Capacity	7
Load Time	.3
Unload Time	.3
Task Selection S...	First In Queue
Travel Logic	
Initial Desired ...	2.0
Initial Network	Global
Routing Logic	
Initial Priority	1.0
Initial Node (Ho...	Output@Source1
Routing Type	On Demand
Idle Action	Remain In Place
Process Logic	
Reliability Logic	
Add-On Process Triggers	
Dynamic Objects	
General	

Transport Logic
Transport Logic

Workstation and Resources

The Workstation is by far the most complex model in the Standard Library. The Workstation is similar to a Server with capacity one, except that it models the *Processing* station in far more detail. The *Processing* station is represented by an operation that is divided into three distinct activities: *SetupActivity, ProcessingActivity,* and *TeardownActivity*. Each entity moving through the Workstation will perform each of these activities within the Processing station.



The entities passing through the Workstation represent a production lot, where the number of items in the lot is specified by the *Operation Quantity*. There is a single setup activity required before starting production for the lot, and a single teardown activity performed once the production lot is completed. During processing the production lot may be divided into smaller production batches that are sequentially processed.

The time required for the *SetupActivity* is determined based on the *Setup Time Type*, which can be specified as *Specific, Change Dependent,* or *Sequence Dependent*. The last two options dynamically calculate the setup time based on an *Operation Attribute*. The *Operation Attribute* is an expression evaluated for the entity that typically involves one or characteristics (e.g. color, size, etc.) that are selected from a list. In the case of a *Change Dependent* setup we have two possible setup times – one if the *Operation Attribute* expression remains the same (e.g. same color as last operation), and one if this value changes. In the case of a *Sequence Dependent* setup the time is given by a Changeovers matrix that is defined in the Data window. To create a Changeover matrix you must first define a list of possible values (e.g. *Small, Medium*, and *Large*, or *Red, Green, Blue*), and then specify that list for use in defining the matrix. In this case each possible changeover (e.g. from *Small* to *Large*) has a different setup time.

Once the *SetupActivity* is complete the *ProcessingActivity* is started. By default the entire production lot is processed as a single batch, however you can also specify a smaller batch size using the *Processing Batch Size* property.

The *Other Requirements* category includes properties for specifying additional constraints on the production process. Clicking on the repeating dialog button in the *Secondary Resources* property opens up the Secondary Resources – Repeating Property window where you can define one more additional resources that are required during one or more activities. For example you might require an operator during setup and teardown, and a tool during the entire operation. You can specify a specific resource that you require, or you can select a resource from a list using a selection goal and condition. In the case of a moveable resource (e.g. a Vehicle or Worker) you can request that the resource visit a specific node before the activity can begin. For simple fixed resources you can place instances of the Resource definition into your model and employ these as secondary resources.

Each batch that is processed can both consume materials at the start of processing, and produce materials at the end of processing. Materials are defined using the Elements panel in the Definitions window and have an *Initial Quantity* and a *Bill of Material* that defines a list materials and quantities required to produce each unit of the material (e.g. a material named Bike might have a bill that includes 2 Wheels, a Frame, a Fork, etc.). The material that is consumed or produced can be specified as either a single *Material* (e.g. Bike), or as the *Bill of Materials* (e.g. the bill for Bike).

In some cases it is desirable to not start a production lot unless the entire lot can be produced within a specified makespan. For example it may not be desirable to start a lengthy operation immediately before shutting down for the weekend. If you specify the *Maximum Makespan* then the estimated makespan plus the *Makespan Buffer Time* must be less than this *Maximum Makespan*. Note that the *Makespan Buffer Time* is a safety factor to account for unexpected delays.

The estimated makespan is computed based on the shift pattern of the workstation, but does not take into account shift patterns for secondary resources or material shortages. These are fully accounted for, however, in the actual makespan for the production lot. Hence it is possible that a production will start based on its estimated makespan but end up violating the maximum due to constraints.

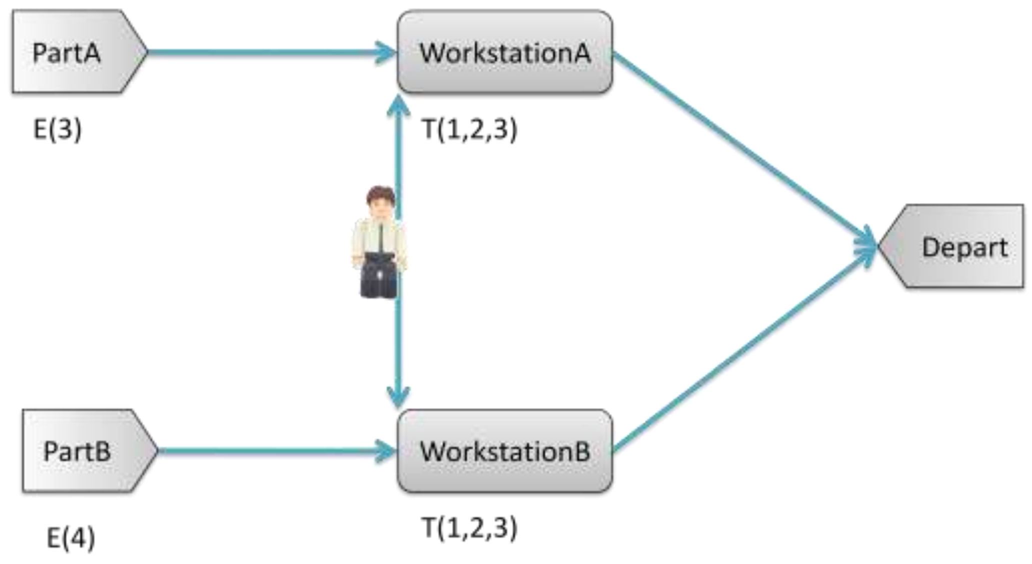
Worker

The Standard Library has a transporter definition named Worker that defines a moveable resource that may be seized and released for tasks as well as used to transport entities between nodes. A Worker object is typically used to model operators, doctors, technicians, etc. To use the Worker you drag a Worker object from the library and place it anywhere in the facility model. You then click on this Worker object to edit its properties.

In contrast to the Vehicle that supports a *Routing Type* that can be *On Demand* or *Fixed Route*, the Worker is assumed to always operate in an on demand mode – i.e. the Worker always waits for either a visit request or a transport request. The Worker always assigns priority to seize visit requests over transport requests. Unlike the Vehicle, the Worker has the ability to follow a work schedule. When following a work schedule an *Off Shift Action* can be specified as Go *To Home*, *Park at Home, Part at Node*, or *Remain in Place*.

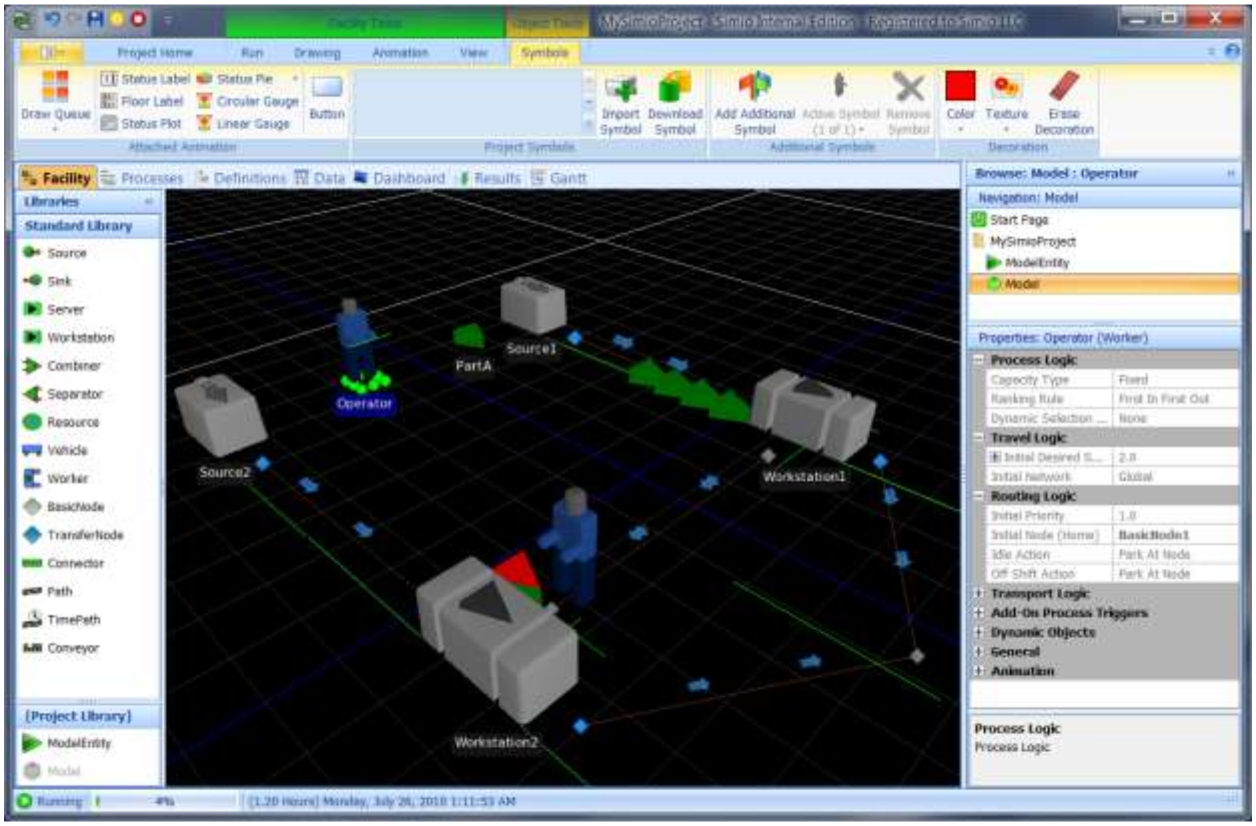
Example: Moveable Operators

In this example we have two part types that are produced on separate machines that share a single operator. PartA has an exponentially distributed inter-arrival time with a mean of 3 minutes, and a service time in minutes given by a triangular distribution with a minimum of 1 minute, mode of 2 minutes, and a maximum of 3 minutes. . PartB has an exponentially distributed inter-arrival time with a mean of 4 minutes, and a service time in minutes given by a triangular distribution with a minimum of 1 minute, mode of 2 minutes, and a maximum of 3 minutes. The operator is required for processing on either machine, and travels at a rate of .5 meters per second over the 10 meter distance between the machines.



Begin by opening Simio and selecting a new model Project. Now place two Workstations (approximate 20 meters apart), two Sources, and a Sink and connect them by paths. Also place two entities from the Project Library and rename them *PartA* and *PartB,* and recolor *PartB* to be red. Change the mean for the *Interarrival Time* on for each of the two Sources, and change the *Entity Type* for *Source2* to *PartB*. Place a BasicNode (default name BasicNode1) near *WorkstationA* and place a second BasicNode (default name BasicNode2) near *WorkstationB*. Click on each node and add an attached queue to animate the entities in *ParkingStation.Contents*. Draw a Path between these nodes and size it to 10 meters, or set Drawn to Scale to false and set its logical length to 10 meters. Change this path *Type* to be *Bidirectional*.

Now drag an object from the Worker definition in the Standard Library and place it in your facility model and name it *Operator*. Select a symbol from the Project Symbols in the Symbols ribbon to represent the *Operator*. Select *Workstation1* and change the parameters for the processing time, and then open *Other Requirements*, click on the Secondary Resources button, Add a new resource named *Operator*, and under Advanced Options select the *To Node* option for *Request Visit*, and specify the *Node Name* as *BasicNode1*. This will cause *Operator* to travel to *BasicNode1* before processing will start at Workstation1. Repeat these same steps for *Workstation2*, except specify the *Node Name* as *BasicNode2*. The model is now ready to run and is shown below.



Properties: Operator (Worker)

Process Logic	
Capacity Type	Fixed
Ranking Rule	First In First Out
Dynamic Selection ...	None
Travel Logic	
Initial Desired S...	2.0
Initial Network	Global
Routing Logic	
Initial Priority	1.0
Initial Node (Home)	BasicNode1
Idle Action	Park At Node
Off Shift Action	Park At Node
Transport Logic	
Add-On Process Triggers	
Dynamic Objects	
General	
Animation	

Process Logic
Process Logic

Note that if *Operator* does not appear waiting at *BasicNode1* or *BasicNode2*, you probably need to lengthen the attached animation queue for the node.

Summary

The Standard Library provides a generic set of object definitions for modeling a wide range of applications. As we will discuss in Chapter 6 you can easily build your own library objects to use in place of the Standard Library. However you can also extend the behavior of the Standard Library definitions using add-on processes. This is a powerful capability that dramatically expands the flexibility and use of this Library. The use of add-on processes is the focus of our next chapter.

Chapter 4: Processes

Overview

Object-based tools such Simio are very good for rapidly building models. You simply drag objects into the workspace, set the properties for those objects, and your model is ready to run. However the traditional problem with this approach is modeling flexibility. It's extremely difficult to design a set of objects that work in all situations across multiple and disparate application areas without making the objects overly complicated and difficult to learn and use.

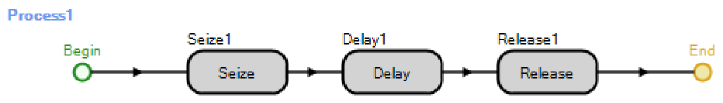
The Simio Standard Library addresses this problem through the concept of add-on processes. An add-on process is a small piece of logic that can be inserted into the Standard Library objects at selected points to perform some custom logic. This custom logic can be used to seize/release resources, make assignments to variables, change travel networks, evaluate alternatives, etc. The processes are created as graphical flowcharts without the need for programming. Hence Simio combines the benefits of object-based modeling (i.e. ease of learning and rapid modeling) with the power and flexibility of graphical process modeling.

Process logic can be inserted into an object on an instance by instance basis, without modifying or changing the main object definition. For example one Server instance might incorporate process logic to seize and move a secondary resource during processing, while another instance for the same Server definition incorporates special logic to calculate the processing time based on a learning curve, and a third instance of the same Server incorporates special process logic for modeling a complex repair process. All these instances share the same Server definition but customize each instance as needed.

Another thing that is particularly powerful about add-on processes is that – unlike a programming insert - processes can span simulated time. For example a process can wait for tank to fill, a resource to become idle, or a queue to reduce to a specific size. Hence processes are not only easier to learn, create, and understand, they are also significantly more powerful than programming inserts.

Processes

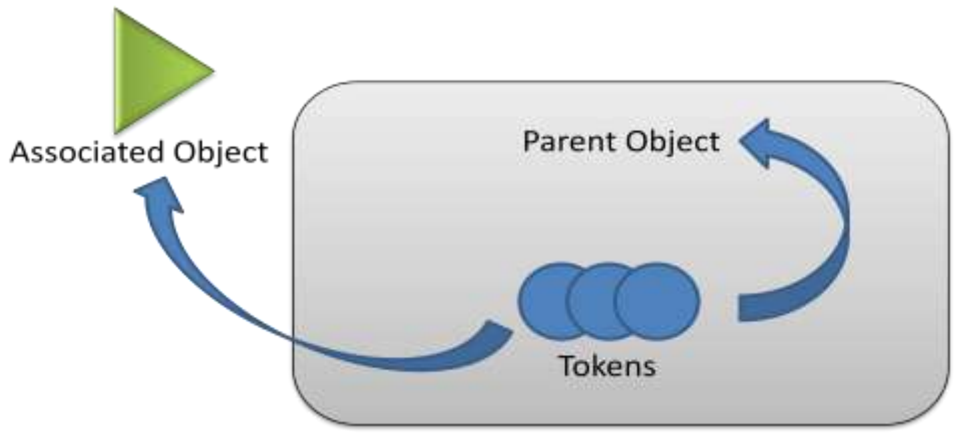
A **process** is a sequence of **steps** that is executed by a **token** and may change the state of one or more **elements**. As the token moves through the process it executes the actions as specified by the step. A single process may have many active tokens moving thru it in parallel. For example the following simple process flow waits to seize a resource, delays by time, and then releases the resource. There may be multiple tokens waiting in the queue to seize the resource, as well as multiple tokens in the Delay step (assuming the resource has a capacity > 1). Note that each step will have properties that govern its behavior – e.g. the Delay step has a property that specifies its delay time.



A process always executes within the context of a parent object. When you create a new process in your model the parent object is your model. The properties that are specified for each step may reference properties and states that are "visible" within that context. These properties and states include those that are owned by the model, as well as objects or elements that have been placed into the model. If you have objects that contain other elements or objects in their model definition, then they are also in the context as long as they have been defined with a public scope.

The token that executes a process may also carry its own properties and states. For example a token might have a state that tracks the number of times the token has passed through a specific point in the logic. In many cases you can simply use the default token in Simio, however if you require a token with its own properties and states you can create one in the Token panel within the Definitions window.

A token carries a reference to both its parent object and its associated object (if any). The associated object is the related object (separate from the parent object) that triggered this process to execute. For example a process that is triggered by an entity arriving to an object will have that entity as the associated object. The process logic can reference properties, states, and functions of both the parent object (i.e. the current model) and the associated object. Hence the token could reference the arriving entity to specify the delay time on the Delay step. To reference the associated object it is necessary to precede the property or state name with the object class name. For example *ModelEntity.TimeCreated* would return the value of the *TimeCreated* function for the associated object of type *ModelEntity*. A runtime error occurs if the associated object is not the specified type.



The steps in Simio have properties – but do not have states. Hence steps can have input values that control their behavior, but cannot have variables that change value during the run. The ability to hold changeable state information is provided by Simio elements. Many of the steps in Simio reference a specific element (or object, since an object is sub-classed from element). For example the Consume/Produce steps (which consume and produce material) reference a Material element. Elements are added to your model using the Elements panel in the Definitions window.

The token also has a *ReturnValue* that can be assigned during the process. The *ReturnValue* is typically used with special processes called decision processes that are executed in zero simulated time (i.e. no time/status delays – such as a Delay step – are permitted) to make a specific decision. For example a process is executed for a Transporter to see if it is willing to accept a new reservation. For a decision process a *ReturnValue* of 0 denotes *False* and a non-zero value denotes *True*.

Process Types

There are three basic types of processes in Simio. All of these processes are built and edited in exactly the same way and only differ in the mechanism that triggers their execution.

A **standard process** is a process that is explicitly defined by and executed by the Simio engine. If you add a standard process to your model you do not have to specify a triggering event since the Simio engine will automatically execute a standard process at the appropriate time. For example the *OnInitialized* standard process is automatically called for each object by the Simio engine during initialization of the model. You add a standard process to your model by clicking on Select Process icon in the Process window for the model.

An **add-on process** is a process that is incorporated into the model of an object to allow the user of that object to insert their own custom process logic into the model at selected points. The add-on process is automatically executed within the objects model (using the Execute step), and hence there is no need to specify a triggering event for the process. The Standard Library makes extensive use of add-on processes. For example, the Server object provides the following list of add-on processes.

Add-On Process	Logical Point in Server Execution
Initialized	During initialization of the Server model.
Entered	Immediately after an entity enters the Server.
Processing	Just before an entity begins processing.
Processed	Immediately after an entity completes processing.
Exited	Immediately after an entity exits the Server model.
Failed	Immediately after the Server enters a failed state.
Repairing	Just before the Server is about to start its time to repair time.
Repaired	Immediately after the Server returns to a repaired state.
On Shift	Immediately after the Server goes on shift.
Off Shift	Immediately after the Server goes off shift.

These add-on processes give considerable flexibility in terms of extending the logic executed by the Server model. For example in the case of the Server the *Failed* or *Repairing* add-on process could be used to seize a repairman, and then the *Repaired* add-on process could be used to release the repairman.

There are two ways to insert a new add-on process into the model. The manual way is to click on the Create Process icon in the Process ribbon for the Processes window, and then select that process for one of the Add-On Process Triggers in the object that is placed in the facility model. The quick way is to simply double click on the name of the Add-On Process Trigger, which creates the process with a default name and then selects that process for that trigger.

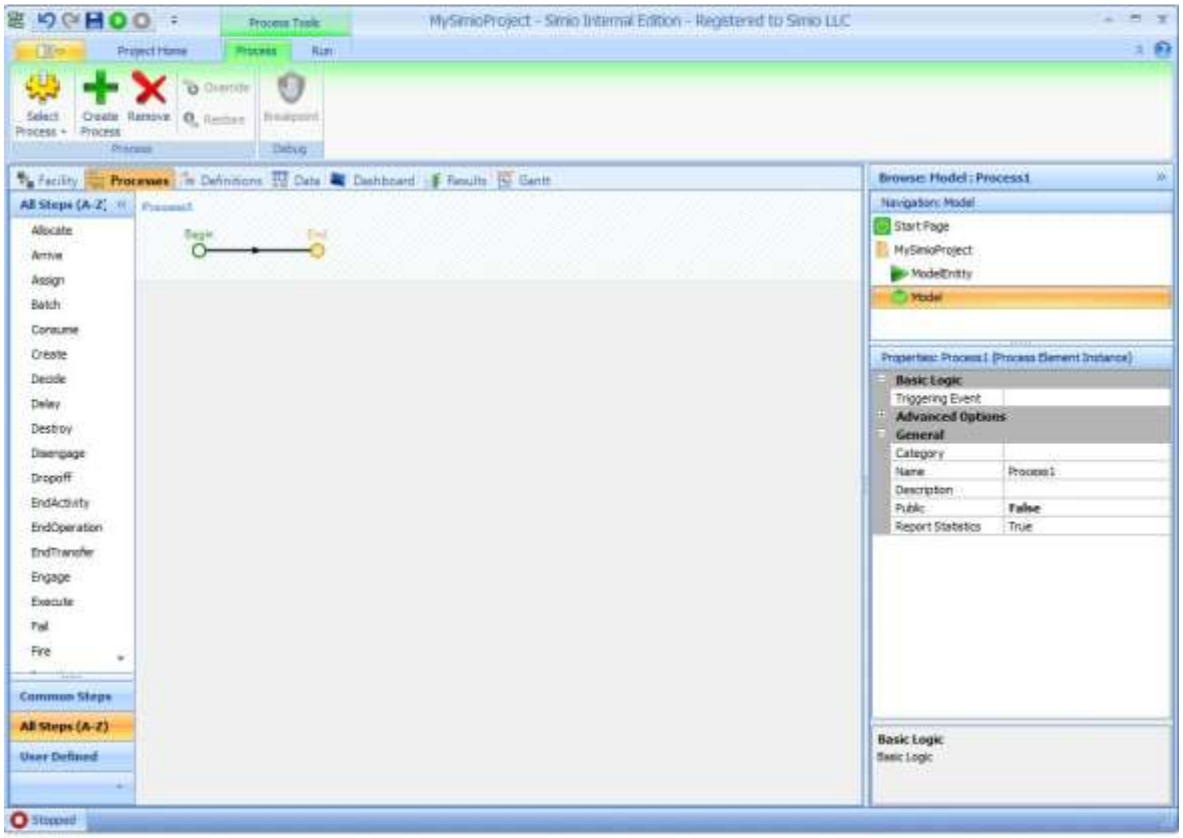
Note that what you are doing with an add-on process is creating a logical process in the context of your model, and then passing that into an object such as a Server to execute inside that model for that only that one instance of the Server. The same add-on process can be passed into any number of objects.

An **event-triggered process** is a process that is triggered by an event that fires within the model. For example a station element named *Input* (which might be used to define an input station within the object) fires an *Input.Entered* event each time the *Input* station is entered. You can have a process be triggered to execute by this event by specifying the *Triggering Event* property for the process as *Input.Entered*. A token will then execute this process each time an entity enters the station, and the associated object for the token will be the entering entity. It is also possible to have multiple triggering events and to dynamically change the triggering event during the running of the simulation by using the Subscribe and Unsubscribe steps in the process logic.

You create an event-triggered process by clicking on the Create Process icon in the Process tab of the Processes window, and then specify the *Triggering Event* property for that process.

Building Processes

You build and edit processes using the Process window shown below. The left side of this window has a fly-out panel for selecting steps, and the right hand side has the navigation panel and properties editor. The steps are categorized by Common Steps, All Steps, and User Defined Steps. The Common steps include the steps that are most frequently used in models. The All Steps include all of the built-in steps for Simio. The User-Defined Steps include user-coded steps that have been added to Simio to extend the core functionality of the product (for details see the Simio User-Extensions Reference Guide).

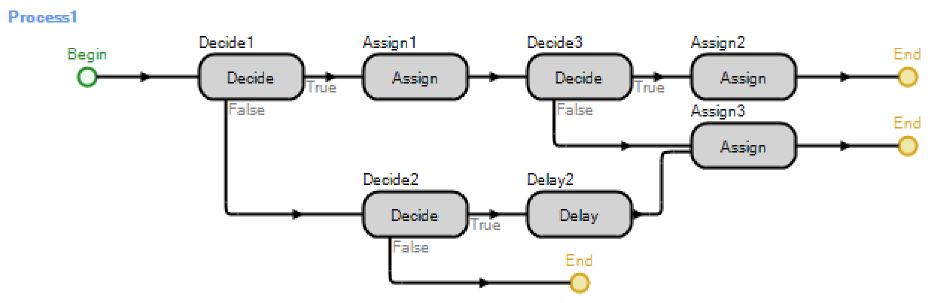


Properties: Process1 (Process Element Instance)

Basic Logic	
Triggering Event	
Advanced Options	
General	
Category	
Name	Process1
Description	
Public	**False**
Report Statistics	True

Basic Logic
Basic Logic

When a new process is added to the window it is shown with a Begin and End point and no steps in between. You add steps to the process by dragging them out from the panel and dropping them at the desired location. Simio incorporates a layout tool that automatically redraws the process as you drop each new step. You can drag a step to move it to a new location within the layout. You can also drag one of the End points to connect it to the input of step. The following shows the result of the automatic layout with multiple Decide steps, where the End coming out of the Delay step has been connected to the input side of the Assign.



You select a step by clicking on the step, and you select the process by clicking outside the steps. If you select a step the properties of the step are displayed in the Property window. If change the properties of a step from their default values and then hover over the step a box will appear showing the nondefault properties. If you select a process the selected process is shown with slanted hash lines and the properties for the process are displayed in the Property window. You can zoom the selected process in an out using the + and – keys. If the process drawing is wider the window you can pan left and right by clicking anywhere in the process outside of a step and dragging left and right.

The process properties include the *Triggering Event* (only used for event-triggered processes), and the *Token Class Name* for the token that executes this process (new Token Classes can be defined using the Tokens panel in the Definitions window). The property named *Token Associated Object Destroyed Action* specifies what should happen to a token running this process if the associated object that triggered this process happens to get destroyed while this process is running. The *Initially Enabled* property allows you to set the initial value of the enabled state for the process. Under *General* you can assign the process to a new or existing *Category*, specify the *Name* for the process, give it a *Description*, define if it has *Public* scope, and specify if the process should *Report Statistics*. Note that all processes assigned to the same category will be grouped together and the groups can be individually collapsed and expanded. You can copy and paste processes. If you paste a process external to Simio (e.g. in a Word document) you can use the Special Paste option to past the process as either a bitmap drawing or as an XML description.

Steps and Associated Elements

The key to process modeling is gaining an understanding of the functionality of the available steps and elements, and how to combine these into process flows to model different aspects of the system. Some of the steps and elements you may use quite often, and others you may never use. One way to approach learning these steps is to get a brief understand of all the steps, a more detailed understanding of the common steps, and then learn the steps in detail as the occasion arises for the their use. Hence we will proceed with a broad overview of the types of actions supported by the various steps and elements, without including all of the details for the steps (detailed descriptions of the steps and elements may be found in the Simio Reference Guide). We will then give a number of examples of the use of these steps for extending the logic of the Standard Library.

As noted earlier many of the steps in Simio reference elements that hold changeable state information on the system. The elements are added using the Elements panel in the Definitions window. A summary of the Simio elements is shown in the following table:

Element Name	Description
Station	Defines a capacity constrained location within an object.
Timer	Fires a stream of events according to a specified *IntervalType*.
Failure	Defines a failure state for the parent object.
BatchLogic	Forms a batch by matching entities together and attaching them to a parent entity.
Storage	Defines a queue for temporarily storing one or more entities in a specified order.
Monitor	Fires an event when states change or cross a specified value.
Network	Defines a network of links.
RoutingGroup	Defines routing logic for selecting a destination node from a candidate node list.
OutputStatistic	Defines an expression that is recorded at the end of each replication.
StateStatistic	Records time-persistent statistics on a state variable.

TallyStatistic	Holds summary statistics for observational values recorded using a Tally step.
Operation	Defines a sequence of activities that are preformed over time.
Activity	Defines an activity that is performed within an operation.
Material	Defines a material that can be produced or consumed and own a bill of material.

Most of the steps are general purpose steps that can be used by any of the five object types. However some steps are specific to a specific object type such as an entity, transporter, node, or link.
We will begin first describing the general purpose steps which are summarized in the following table. Note that the shaded steps are those included in the Common Steps list and are the ones most often used. Where appropriate the elements that are referenced by the steps are also noted. Elements are added to the model using the Elements panel in the Definitions window.

General Purpose Steps

Step Name	Action
Assign	Assigns an expression value to a state variable.
Decide	Sends the token to one of two exit points based on an expression.
Delay	Delays the token for a specified time.
Execute	Executes a process and either waits or continues.
Tally	Tallies a value in the specified TallyStatistic element.
Create	Creates a new entity.
Destroy	Destroys the parent or associated entity.
Fire	Fires the specified object event.
Wait	Waits for a specified event to fire.
Seize	Seizes one or more resource objects.
Release	Releases one or more resource objects.
Transfer	Transfers the associated entity between objects and/or free space or between stations.
EndTransfer	Completes the transfer of the associated entity into the object and/or station.
Allocate	Manually trigger resource allocation for the parent object.
Batch	Create a batch with the associated entity using the BatchLogic element.
Consume	Consume a specified quantity of material.
EndActivity	End the current operation activity for the associated entity.
EndOperation	End the current operation for an entity.
Fail	Specifies a Failure element to change to a failed state.
Insert	Insert the associated or parent object into a queue.
Interrupt	Maybe be used to interrupt process delays.
Produce	Produces a specified quantity of a material.
Remove	Remove the associated or parent object from a queue.
Repair	Specifies a Failure element to restore to a repaired state.
Resume	Resumes a suspended process or movement of the parent or associated object.
Search	Search a collection of items including table rows or objects in a list or queue.
SetNetwork	Sets the current network for the parent or associated object.
SetNode	Sets the current destination for the parent or associated object.
SetTable	Sets a table reference and row for the token or parent/associated object.

StartActivity	Starts a specified activity for an operation.
StartOperation	Starts a specified operation.
Subscribe	Adds a new triggering event to a process.
Suspend	Suspends a process or movement of the parent or associated object.
UnSubscribe	Removes a triggering event for a process.

The **Assign** step is used to assign an expression value to one or more state variables. The Assign step displays a single assignment in the main properties grid, but allows for additional assignments in the Repeating Properties Editor.

The assignment action is to evaluate the specified *Value* expression, and assign that value to the specified *State Variable Name*. A state variable may be added to your model by selecting the States panel in the Definitions window for the model and then clicking on one of the four state icons in the States ribbon. Note that a state added to your main model can be thought of as a global variable, while a state added to an entity model or other object may be thought of as an attribute of that entity or object.

A **discrete state** is the most commonly used state variable and can be assigned any real value. By default a discrete state variable is a simple *Scalar*, but it can also be dimensioned as a *Vector*, a *Matrix*, or an array up to 10 dimensions. In the later case you enter a number for *Dimensions* instead of selecting from the drop list. In the case of a vector or matrix you can also both dimension and initialize a state variable using the values in a data table by selecting the Dimensions property as [Table]. In this case the number of rows and columns for the matrix are set to the number of rows and columns in the table, and the matrix is initialized to the table values. As we will see in Chapter 5 this is a very convenient way to both dimension and initialize arrays using external data.

A **level state** is a variable that is described by both a rate and level. For example if you create a level state named *Tank*, you can reference the level value by *Tank*, and the corresponding rate value by *Tank.Rate*. Note that the *Tank* value automatically updates based on the current value assigned to *Tank.Rate*.

A movement state is a state that can have a rate, acceleration, acceleration duration, heading between 0 and 360 degrees, and a pitch relative to the floor measured in degrees. If you create a movement state variable named *Travel*, then the value *Travel* will be the total distance traveled, and the values for *Travel.Rate, Travel.Acceleration, Travel.AccelerationDuration, Travel.Heading,* and *Travel.Pitch* will be the related parameters for the state.

A **list state** is a state variable that can be assigned a value from a list (list are defined using the List panel in the Definitions Window). For example a list named *Color* with *members Red, Green, Blue* could be used to define a list state name *ColorValue*. The numeric value of a list is referenced using the keyword *List*. Hence assigning *ColorValue* to *List.Color.Blue* would set *ColorValue* to the color list member *Blue*. All state values return a numeric and in the case of a list state this is the zero-based index into the list, or in this case a value 2 since Blue is a zero-based index 2.

Note that if you are adding state variables to one more entity models, and then creating objects for those entities, you must reference the states of the entity by prefixing the state names with the entity model name. For example if you create an entity model named Part, and then give it discrete states X and Y, you reference these states as Part.X and Part.Y.

In addition to the Assign step, there are several other steps used to set dynamic characteristic of an entity/object including **SetNetwork** (specifies the network to follow), **SetNode** (specifies the destination to travel towards), and **SetTable** (specifies a row in a data table for retrieving data).

The **Decide** step is used to select one of two exit points based on the value of an expression. The expression is interpreted either as a logical condition or a probability based on the *Decide Type* property.

The **Delay** step is used to delay the token by a specified time. This step is typically used to model general processing delays in the system.

The **Execute** step is used to execute another process. This step will either hold the current token until the specified process is completed, or continue and execute in parallel to the spawned process.

The **Tally** step is used to record a value for a specified TallyStatistic element. To use the Tally step you must first add a **TallyStatistic** element to your model. The Tally can record either the value of an expression, or the time between arrivals to the TallyStatistic based on the *Value Type* property specified for the step. Note that *Token.TimeInProcess* can be used in the expression to record the time that the token has spent in the process, and *Entity.TimeInSystem* can be used in the expression to record the time that the associated entity has spent in the system.

The **Create** and **Destroy** steps are used to create and destroy dynamic objects which include entities and transporters. The Create can either create a new dynamic object, or create a copy of either the parent object or associated object. The Destroy step can destroy either the associated object or the parent object (i.e. destroy itself).

The **Fire** and **Wait** steps provide coordination between logical points within an object, or between objects. The Fire step is used to fire an event that has been defined for the object (events are defined using the Events panel in the Definitions window). The Wait step is used to hold an entity until a specified event has been fired. The Wait step also includes a *Release Condition* property that if specified must be true for a token to be released.

The **Seize** and **Release** steps are used to seize and release capacity of an object that has been defined as a resource. As noted in Chapter 3 that Resource object can be used to model fixed resources, and the Vehicle object or an Operator entity can be used to model a moveable resource. Both the Seize and Release steps utilize the Repeat Group Editor to allow for multiple seizes and releases at a single step. Note that in the case of the Seize you can request a visit by a moveable resource using the *Request Visit* property under Advanced options.

The **Transfer** and **EndTransfer** steps are used to initiate and complete entity transfers between objects, between an object and free space, or between stations within an object. At the completion of the transfer the EndTransfer step fires the entity's *Transferred* event. These steps are used to provide a "handshake" between objects in the model. We will discuss the use of these steps in detail in Chapter 6 where we discuss building custom objects.

There are a number of steps that are specific to modeling the behavior of entities and transporters. Since the transporter is sub-classed from entity, any of the entity steps can also be used within the model of a transporter. These steps are shown below:

Entity Steps

Step Name	Action
Arrive	Notifies the visit request that the entity has arrived to the requested location.
PlanVisit	Search for and accept a ride pickup or visit request as a planned node visit.
SelectVisit	Select a planned node visit and set the destination to the selected node.

Transporter Steps

Step Name	Action
Dropoff	Drop off a passenger entity at the current node.
Pickup	Pickup a passenger entity from the RidePickupQueue at the current node.
SelectDropoff	Set the destination to a selected passenger entity in the RideQueue.

There are also a number of steps that are used for modeling the behavior of a node object. Note that the **Park** and **UnPark** steps can also be used within a model of an entity or transporter by referencing the parent object rather than the associated object.

Node Steps

Step Name	Action
Park	Park the associated or parent entity in the parking area of a node.
Ride	Initiate a transporter ride request for the associated entity.
Route	Set the destination for the associated entity using a RoutingGroup element.
UnPark	Move the parked parent or associated entity into the crossing area of the node.
VisitNode	Execute the OnVisitingNode standard process for the associated entity.

There are also two special purpose steps that are used in modeling link behavior as summarized below:

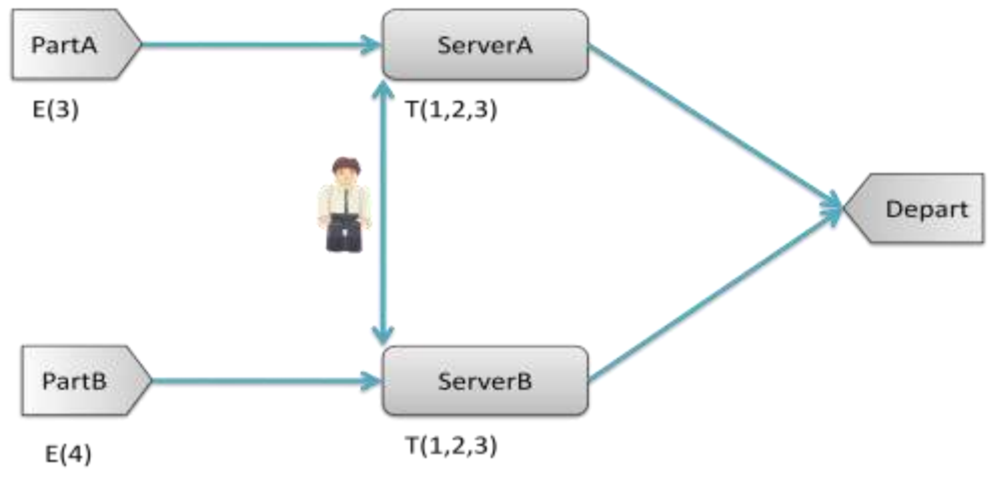
Link Steps

Step Name	Action
Disengage	Unlock the entity from the link so that it can move independently.
Engage	Lock an entity to the current location or nearest cell location on the link.

We will now turn our attention to using a number of these steps in the following examples.

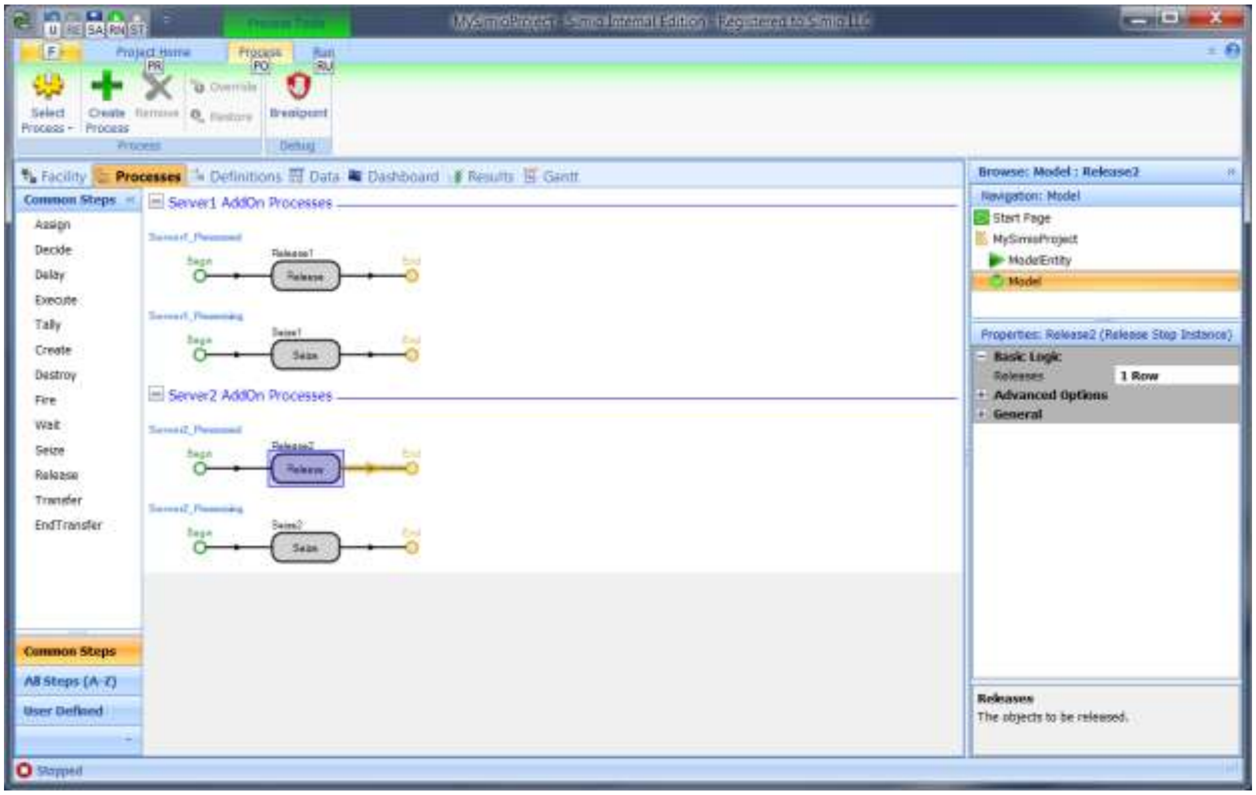
Example: Using a Moveable Resource with Server (Seize/Release)

In Chapter 3 we modeled a simple system with two workstations requiring an operator to move back and forth to process a part on the workstation. We used the Workstation object to because it includes support for secondary moveable resources. We will now redo this same example but use Server objects in place of the more complicated Workstation object. We will employ add-on processes to add this missing functionality in the Servers in terms of seizing and releasing the operator. While we at it we will also briefly look at the logic that has been automatically added to the operator to allow it to respond to move request from the Servers.



We proceed by building our model as before, only using Servers in place of Workstations. We add the missing resource logic to the Servers by inserting add-on process for the triggers named *Processing* and

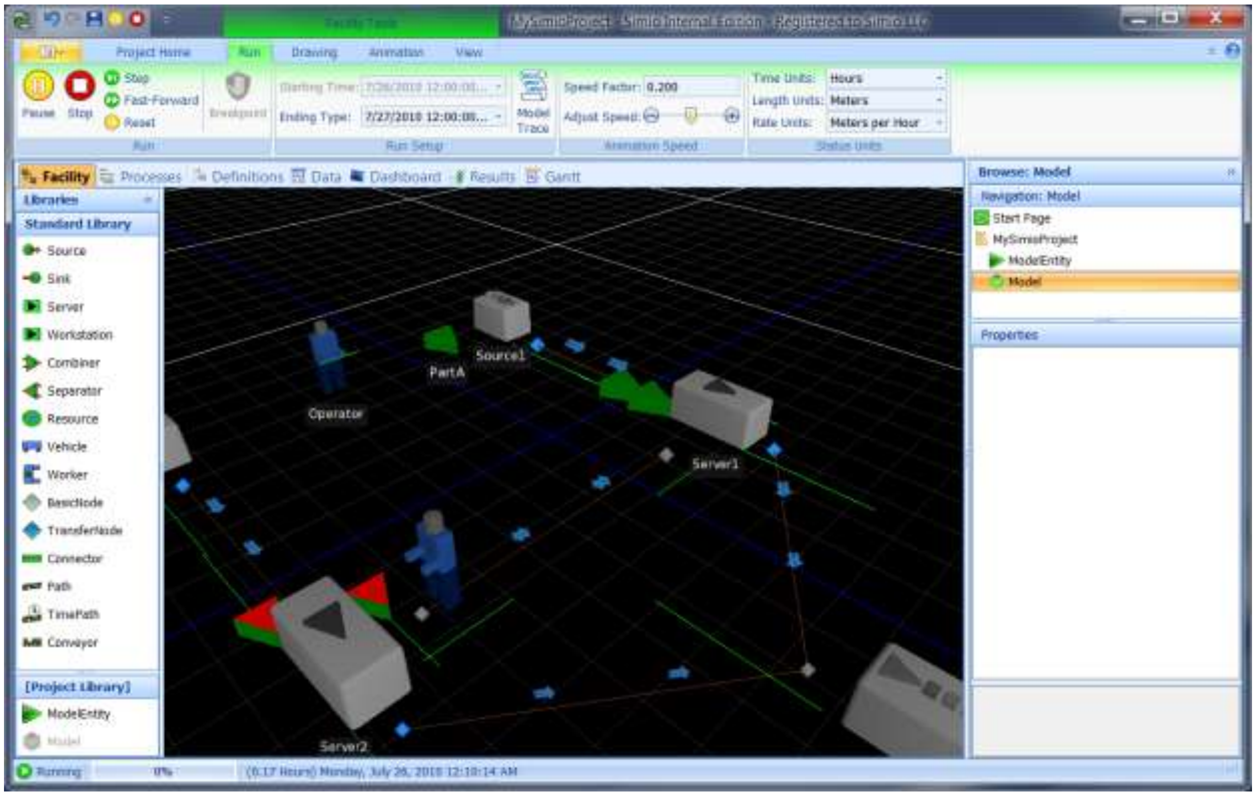
Processed. The *Processing* trigger occurs immediately before processing begins, and the *Processed* trigger occurs immediately after processing is completed. We will add a Seize step to each *Processing* add-on process, and a Release step to each *Processed* add-on process, as shown below.



Properties: Release2 (Release Step Instance)
Basic Logic
Releases: 1 Row
Advanced Options
General

Releases
The objects to be released.

On the Seize steps we specify *Operator* as the resource to seize, and under the *Advanced Options* we specify a visit request to *BasicNode1* for *ServerA*, and *BasicNode2* for *ServerB*. On the Release step we specify *Operator* as the resource to release. The model is now ready to run and is shown below:



Summary

The chapter has introduced the concept of process logic for adding new behaviors to our existing modeling objects. The ability to insert process logic into individual instances of an object is an extremely powerful capability in Simio. In Chapter 6 we will expand further on these concepts when we discuss process concepts for building object libraries.

Chapter 5: Data Driven Models

Overview

Simulation models typically have data that is used to drive the model. In some cases this data is conveniently entered directly into the modeling objects. For example with simple flow line making a single part it might be convenient to "hard code" the inter-arrival time and processing times directly into the properties for the objects in the model. However in many cases there is a large amount of data as well as a desire to frequently change the data. In addition the people using the model with different sets of data may not be the same person that builds the model. In these cases it is convenient to be able to define the data in data tables and then have the model reference the data in those tables. It may also be desirable to either import or directly bind the data tables to external data sources such as Excel or a database. This chapter describes the features in Simio for building data-driven models using data tables that interface to external data sources.

Data Tables

A Simio data table is a data container that has a collection of user-defined columns with corresponding rows of data. Each column can hold a specific type of data such as a string, real number, Boolean, date-time, expression value, entity type, etc. Within Simio you can define as many tables as you like, and each table can have any number of columns of different types. You can create relations between tables such that an entry in one table can reference the data held by another table. For example a table of production orders could reference a table of product descriptions.

A data table is defined using the Tables panel in the Data window. To add a new table you click on either Data Table or Sequence Table in the Tables section of the Table ribbon. The sequence table is data table with a column named *Sequence* that has already been added to the table for specifying a routing sequence for an entity. Hence everything that applies to a data table also applies to sequence tables. Once you have added a table you can rename it and give it a description by clicking on the tab for the table and then setting the table properties in the Property window.

If you add multiple tables you can drag the tabs apart and drop them on the layout targets to arrange them as you wish. You can also arrange them into vertical and horizontal tab groups by right clicking any table tab and selecting the appropriate option.

To add columns to a table you select a table to make it active and then click on property types under Standard Property, Element Reference, Object Reference, or Foreign Key. You can then rename the column by selecting the column header and changing the column properties. An element reference is a reference to a Simio element such as a Station or Material. An object reference is a reference to an object instance such as Worker or Lathe. The standard properties are all the other property types in Simio and include the following:

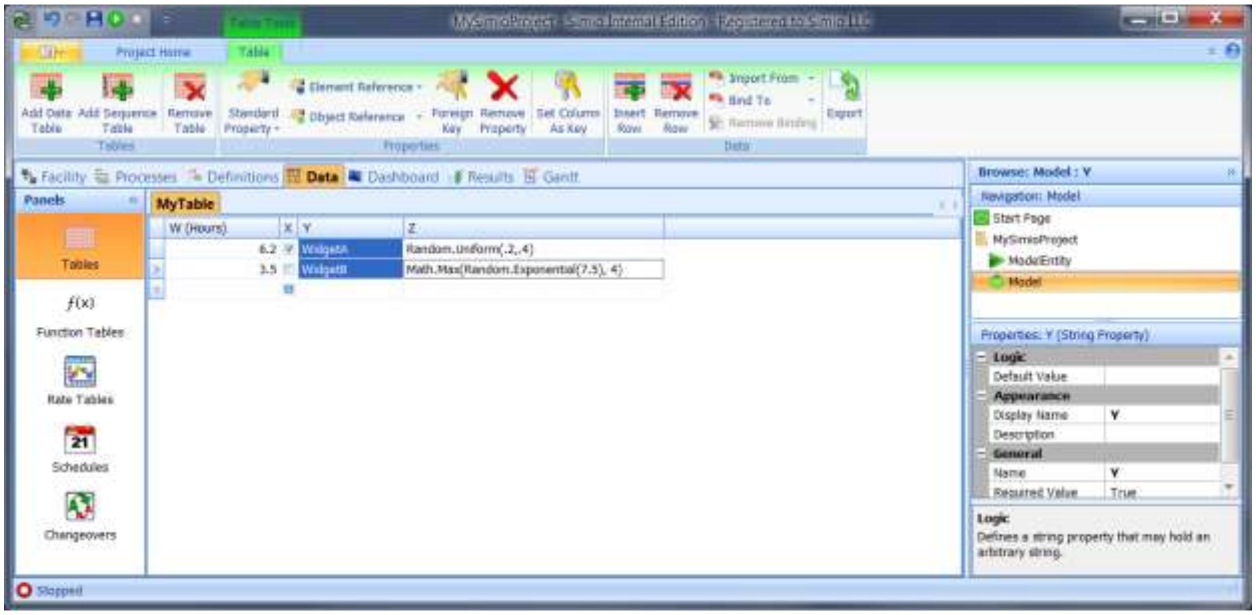
Property Type	Description
Real	A real constant: e.g. 132.7
Integer	An integer constant: e.g. 34 or -27
Boolean	A true/false check box.
Expression	A valid Simio expression involving one or more variables: e.g. *(X + Y) / 2.3*
Date Time	A date time value with a calendar date selector: e.g. *1/1/2010 12:00:00 AM*
String	A valid string: e.g. Fred
Event	An event that is defined in the context of the model: e.g. *ModelEntity.Transferred*
List	A value selected from a list that is referenced by the property: e.g. *Red*
Enumeration	A value from an enumeration that is referenced by the property: e.g. *FirstInFirstOut*
Rate Table	A rate table that is defined for this model: e.g. *ArrivalPattern*
Table	A data table that is defined for this model: e.g. *ProductTable*
Sequence Table	A sequence table that is defined for this model: e.g. *RoutingTable*
State	A state that is defined for this model: e.g. *ReworkCount*
Schedule	A schedule that is defined for this model: e.g. *OverTimeShift*
Selection Rule	A dynamic selection rule: e.g. *Smallest Value First*

Note that some properties have required values that must be set in the Properties Editor for the column to work. For example a List property requires that a list specified that defines the valid options for the column. Hence we create a list named *Colors* with value members *Red, Green,* and *Blue*, and then add a List column referencing the *Colors* list; the valid entries for the column are *Red, Green,* and *Blue*.

The columns that specify numeric values (e.g. Real, Integer, Expression) also have a *Unit Type* property that can be specified. The unit type can be *Time, Travel Rate,* or *Length*, and then the appropriate units can be specified (e.g. Meters, Feet per Minute, etc.).

You can also select a column and make it a Key Column. A key column must have all unique entries in the column. For example a key column of type *Integer* cannot have two rows with the same number. A key column can then be referenced by adding a *Foreign Key* column property in another table, and referencing this table and key column in the properties of the foreign key. This will then link the rows in that table to a row in this table using the unique key value in this column. We will see an example of this later in this chapter.

The following shows an example table named MyTable with four columns named W, X, Y, Z. Column W is a real column with *Unit Type* specified as *Time* and units in *Hours*. Column X is a Boolean column where a check mark indicates True. A Boolean True in Simio has a numeric value of 1. Column Y is a string column and is set as a key column as indicated by the yellow column header. As a result the string entries in this column must be unique. Column Z is an expression column and accepts any valid Simio expression.



MyTable

	W (Hours)	X	Y	Z
	6.2	✓	WidgetA	Random.Uniform(.2,.4)
>	3.5		WidgetB	Math.Max(Random.Exponential(7.5), 4)
*				

Properties: Y (String Property)

Logic	
Default Value	
Appearance	
Display Name	Y
Description	
General	
Name	Y
Required Value	True

Logic
Defines a string property that may hold an arbitrary string.

Once a table is defined you can populate the table with data in several different ways. You can manually populate the table by directly entering data for each cell in the table. Note that the bottom row with the * is a row that has not yet been added – once you enter a value in this row it then becomes an active row being edited as indicated by the pen that replaces the *. You can also copy and paste within this table, between different tables, and between external data sources (e.g. Excel) and the data table. You can also import from or bind to external data sources.

When working with Excel as an external data sources it is often convenient to first define the columns in Simio, and then export the empty table to Excel, and then populate the data inside Excel. You can then import or bind to the spreadsheet. Importing is a manual operation that happens each time you click on import. Binding is an automatic operation; once the binding is established the data is automatically imported at the beginning of each run with no manual intervention.

You can reference a value in the table using the syntax TableName[RowNumber].ColumnName, where RowNumber can be an expression specifying the 1-based row number. For example *MyTable[1].X* would reference the value *6.2*, and *MyTable[1].Z* would reference the expression *Random.Uniform(.2,.4)*.

It is also possible to have either a token or an object reference a specific row in a table using the SetTable step. Once a row has been assigned to the token/object the values in the table can be referenced without appending the [RowNumber]. For example the MyTable.X references the Boolean X value for the row assigned to the token/Object. If a row has been assigned to a token and then that token is used to create a new object that newly created object will reference the same row as the token.

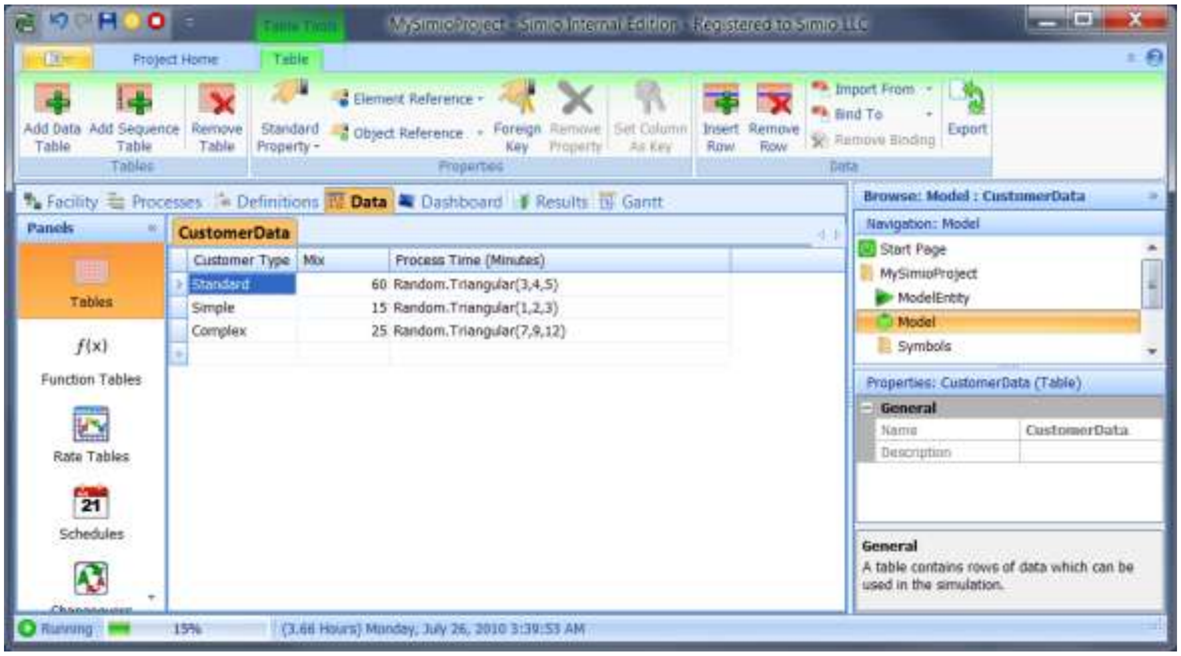
Example: Multiple Entities from a Single Source

In this example we are going to use a table for generating multiple customer types from a single Source. We have three different types of customers that wait in a single line to be processed by two identical servers. The customers arrive according to a Poisson process, with a mean time between arrivals that is exponentially distributed with a mean of 3 minutes. The customer mix (percentage) and the processing time on the server are summarized in the following table.

Customer Type	Mix (Percentage)	Processing Time
Standard	60	Random.Triangular(3,4,5)
Simple	15	Random.Triangular(1,2,3)
Complex	25	Random.Triangular(7,9,12)

To model this we will place a Source, Server, and Sink into our facility and connect them with Paths with *Allow Passing* set to *False*. We will specify the time between arrivals for the Source as an exponential sample with a mean of 3 minutes, and we will set *Input Buffer* on the Server to 0, and set the *Capacity* to 2. The combination of no input buffer on the Server and no passing on the Path will cause our customers to queue up along the path in front of the Server. The capacity of 2 on the Server will allow this single Server object to represent two identical servers. We also place three instances of ModelEntity and rename them *Standard*, *Simple*, and *Complex*, and select people symbols from the symbol library to represent these three customer types.

We will now build a Simio table by selecting the Data window and clicking on Add Data Table and then renaming the table *CustomerData*. Next we will add a column named *CustomerType* by clicking on the Object Reference property and selecting Entity. Next we add a column named *Mix* by clicking on Standard Property and selecting *Real*. We then add a column named *ProcessTime* by clicking on Standard Property and selecting *Expression*. We also set the *Unit Type* for this property to *Time* and set the units to *Minutes*. We then manually enter the data for the table as shown below:



CustomerData

Customer Type	Mix	Process Time (Minutes)
Standard	60	Random.Triangular(3,4,5)
Simple	15	Random.Triangular(1,2,3)
Complex	25	Random.Triangular(7,9,12)

Properties: CustomerData (Table)

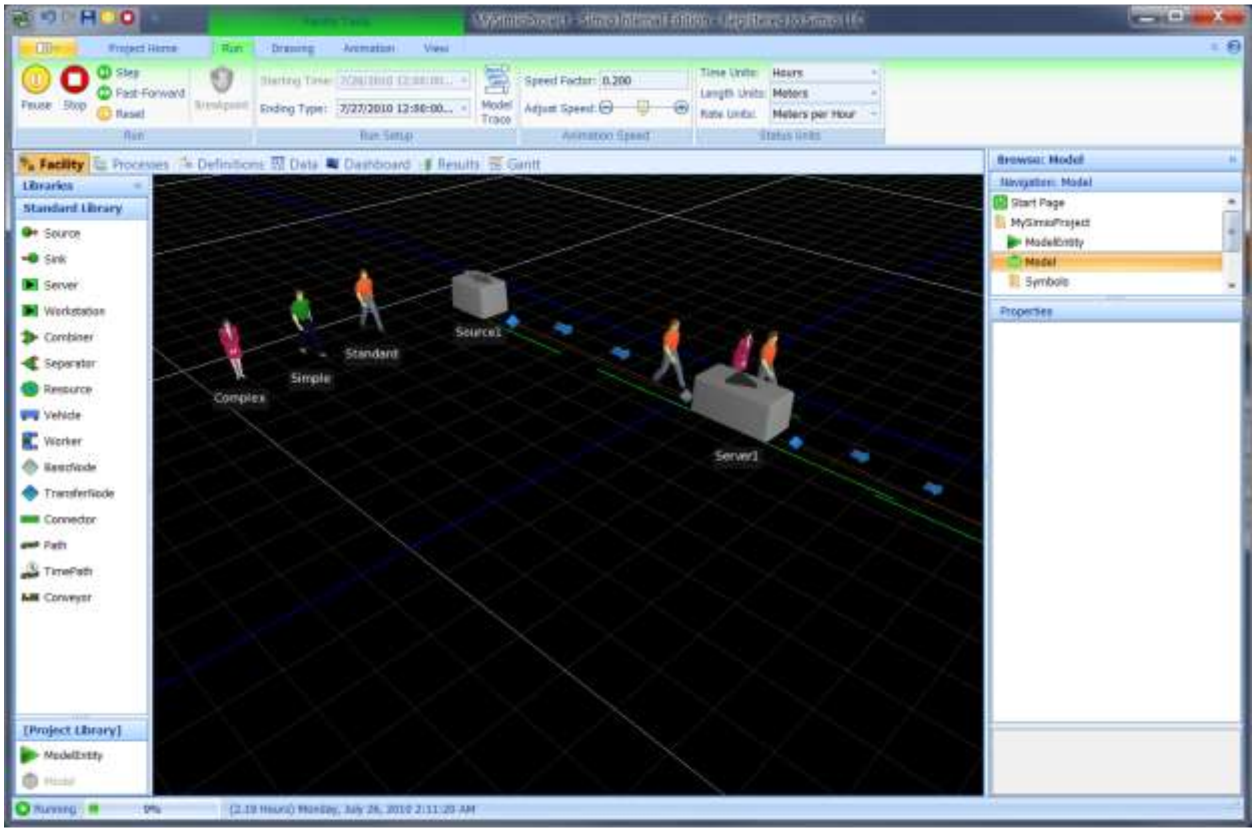
General

Name	CustomerData
Description	

General
A table contains rows of data which can be used in the simulation.

Now that we have this table defined we will use it to select the type of entity to create at the Source, and specify the processing time at the Server. To do this we will specify a table reference assignment for our Source object *Before Creating Entities*. We will specify the *Table Name* as *CustomerData*, and specify the *Row Number* as *CustomerData.Mix.RandomRow*. Note that *RandomRow* is a function that returns a random row number based on the values in the *Mix* column as weights. We can specify the *Entity Type* as *CustomerData.CustomerType*. The newly created entity will then point to this same row. We then change the processing time for the Server to be *CustomerData.ProcessTime*. Hence the processing time will be taken from the *ProcessTime* column for the selected row.

The running model for this example is shown below. Note that you may need to lengthen the Processing.Contents animation queue to see both customers in service at the same time.



This example is simple but illustrates the power of tables for building data driven models. Note that we could also bind this table to an Excel spreadsheet and then do all of our data editing in the spreadsheet.

Example: Product Routings using Separate Sequence Tables

In this example we have three part types with each part type having a different routing through a facility comprised of three servers. The product mix for the three part types is 20% type A, 30% type B, and 50% type C. The routing and processing time for each of the three part types is summarized in the following tables:

PartA

Station	Process Time
Server1	Uniform(.5,.9)
Server2	Triangular(.5,1.1,1.2)
Sink	

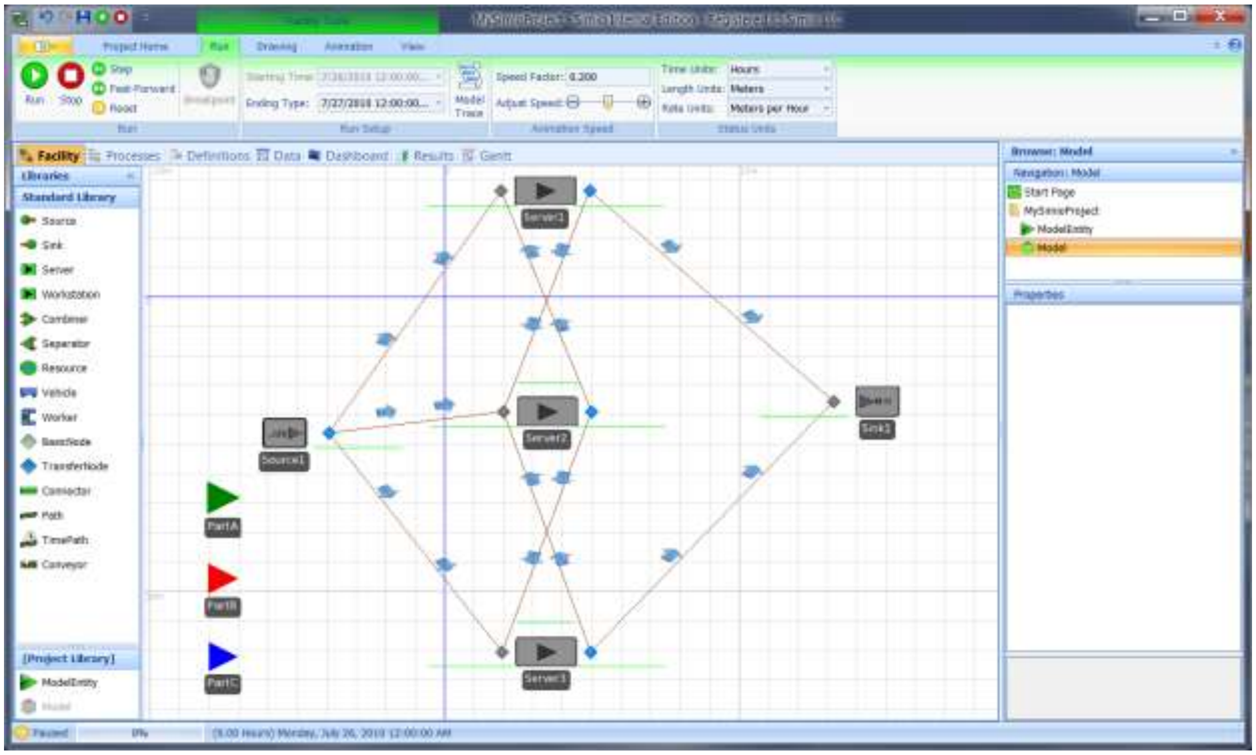
PartB

Station	Process Time
Server3	Triangular(.5,.8,1.2)
Server2	1.5
Server1	1
Sink	

PartC

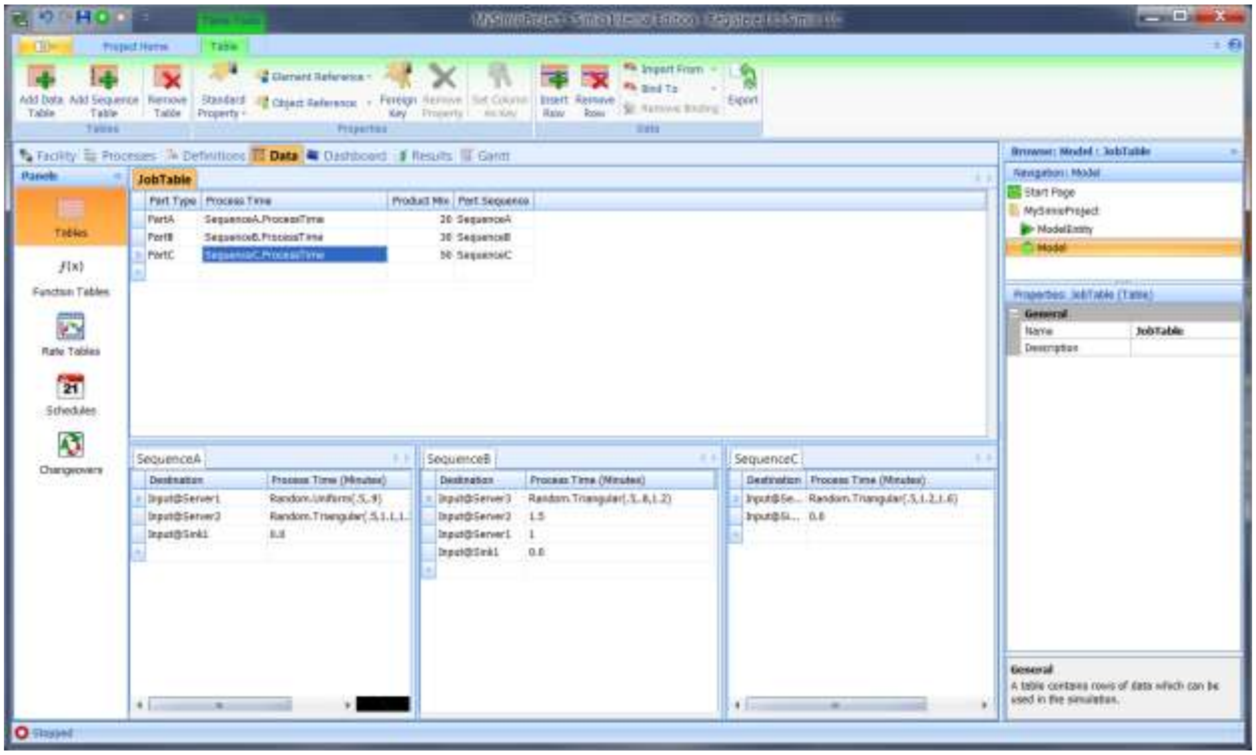
Station	Process Time
Server2	Triangular(.5,1.2,1.6)
Sink	

To model this we will place a Source, three Servers, and Sink, and connect them with a network of paths to allow for movements in all directions as shown below. We set the routing logic for all of the output nodes to *By Sequence*. We have also placed three instances of ModelEntity (PartA, PartB, and PartC).



Next we will build our data tables. In this example we are going to use separate sequence tables for each part type, but in the next example we will redo this same problem using data relations to store all three sequences in a single sequence table. We will add data table named *JobTable*, and sequence tables named *SequenceA*, *SequenceB*, and *SequenceC*. For the sequence tables we will set the *Accepts Any Node* property on the Destination column to False so that we can used the abbreviated notation in 3the routing (i.e. Server1 instead of Input@Server1). We will add one additional column to each sequence table named *ProcessTime.*

For the *JobTable* we will add an Object Reference property of type Entity named *PartType*, and Expression property named *ProcessTime*, a real column named *ProductMix*, and a Sequence Table property named *PartSequence*. The purpose of the *ProcessTime* column is to create an "indirection" to allow us to reference the process time in our model using *JobTable.ProcessTime*, regardless with sequence table is holding the processing time. In a similar way we can reference the part sequence as *JobTable.PartSequence* independent of which part type we have. The following shows the *JobTable* and three sequence tables populated with the appropriate data.



JobTable

Part Type	Process Time	Product Mix	Part Sequence
PartA	SequenceA.ProcessTime	20	SequenceA
PartB	SequenceB.ProcessTime	30	SequenceB
PartC	SequenceC.ProcessTime	50	SequenceC

SequenceA

Destination	Process Time (Minutes)
Input@Server1	Random.Uniform(.5,.9)
Input@Server2	Random.Triangular(.5,1.1,1...
Input@Sink1	0.8

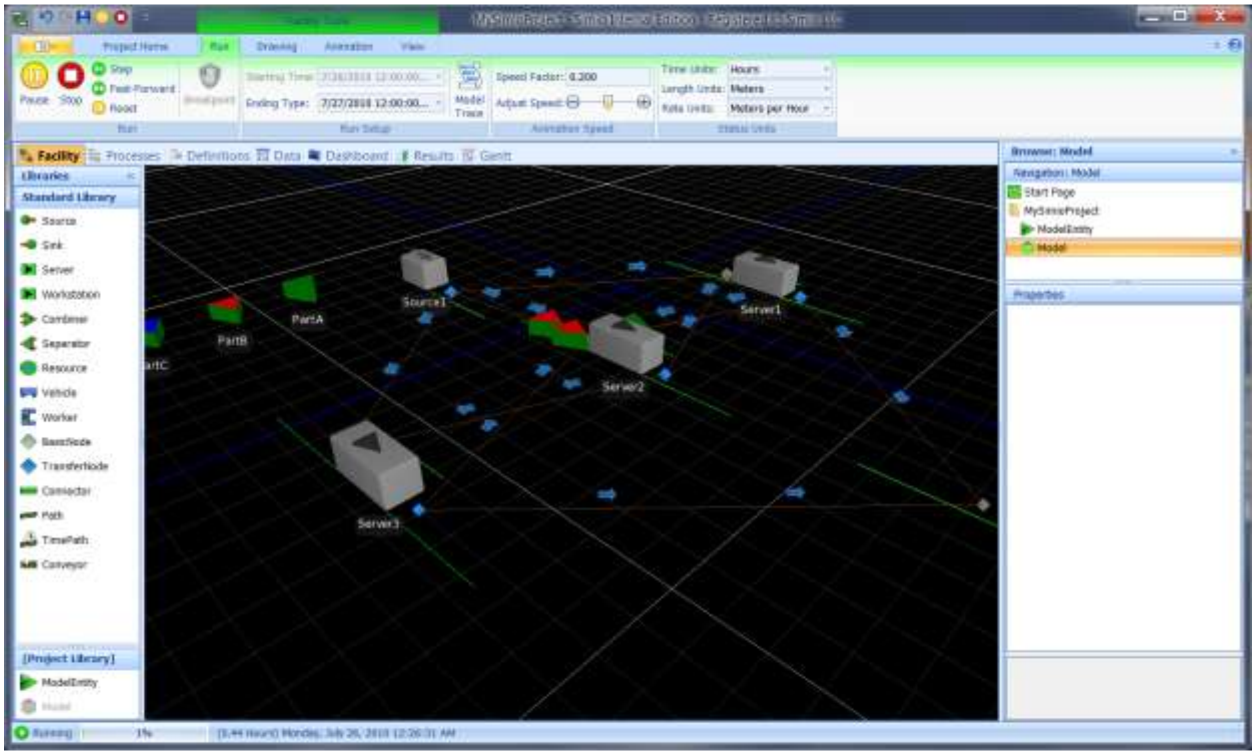
SequenceB

Destination	Process Time (Minutes)
Input@Server3	Random.Triangular(.5,.8,1.2)
Input@Server2	1.5
Input@Server1	1
Input@Sink1	0.8

SequenceC

Destination	Process Time (Minutes)
Input@Se...	Random.Triangular(.5,1.2,1.6)
Input@Si...	0.8

We now table reference assignments at our Source. The first is *Before Creating Entities* (just before entity creation) and sets the active row for the token to a random row in *JobTable* based on the *ProductMix* column. The second is table reference assignment is *On Created Entity* (just after entity creation). We have the entity point to the sequence table specified in the *PartSequence* column in *JobTable*. We can now specify our *Entity Type* on the Source as *JobTable.PartType*, and our processing time on each Server as *JobTable.ProcessTime*. Note that the value returned is retrieved from the active row of the appropriate sequence table for that part type. The following shows our model running.



Example: Product Routings using a Table Relation

We will now redo this same problem using a foreign key to create a table relation. This approach allows us to exploit relational data design to simplify our tables. We keep the same facility model as before, except we will be changing a few table references per our new table design.

In our new approach we will have only two tables: one to hold the job data and one to hold the sequence steps for all three part types. Our basic table design is shown below. The *Job Table* specifies the *Part Type*, *Product Mix*, and the *Sequence Type* to follow. The *Sequence Type* is set as a key column and hence all values in the column must be unique. The Sequences table specifies the *Sequence*, *Sequence Type*, and *Process Time*. The *Sequence Type* is a Foreign Key property that references the *Sequence Type* column in the Job Table. Note that multiple rows in our Sequences table reference the same row in the Job Table.

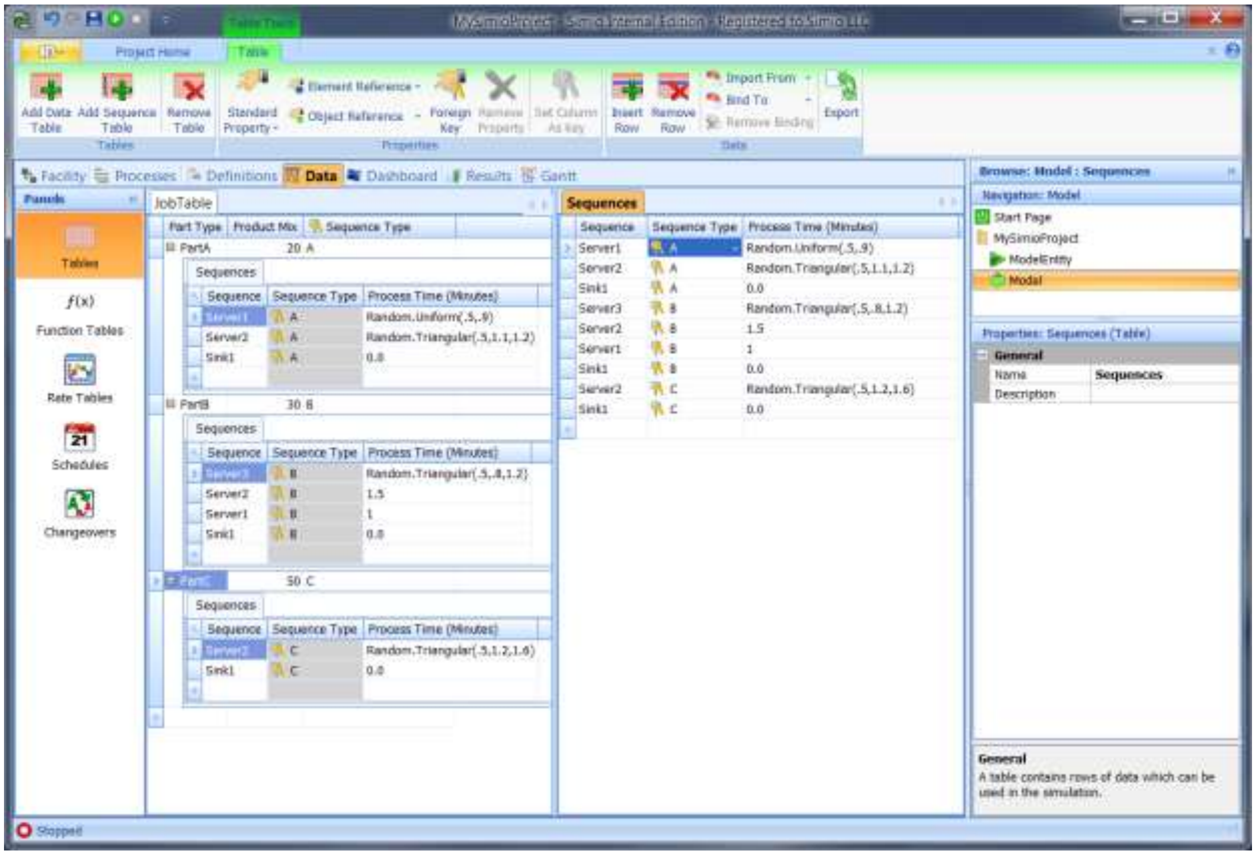
Job Table

Part Type	Product Mix	Sequence Type
PartA	20	A
PartB	30	B
PartC	50	C

Sequences

Sequence	Sequence Type	Process Time
Server1	A	Random.Uniform(.5, .9)
Server2	A	Random.Triangular(.5, 1.1, 1.2)
Sink1	A	0.0
Server3	B	Random.Triangular(.5, .8, 1.2)
Server2	B	1.5
Server1	B	1
Sink1	B	0.0

We build our tables in Simio using Tables panel in the Data window, first creating Job Table, and then creating our Sequences table. We define the Sequence Type in the Job Table as a string column, and then select this column and click on Set Column As Key to make this a key column. We then add our Sequences table, and then click on Foreign Key to add a foreign key property named *SequenceType*, and specify the Table Key for this foreign key property to *JobTable.SequenceType*. The following shows the completed and populated tables. Note that the sequences for each part can be expanded/contracted by clicking on the +/- box to the left of the part name.



JobTable

Part Type	Product Mix	Sequence Type
PartA	20	A
PartB	30	B
PartC	50	C

PartA – Sequences

Sequence	Sequence Type	Process Time (Minutes)
Server1	A	Random.Uniform(.5,.9)
Server2	A	Random.Triangular(.5,1.1,1.2)
Sink1	A	0.0

PartB – Sequences

Sequence	Sequence Type	Process Time (Minutes)
Server3	B	Random.Triangular(.5,.8,1.2)
Server2	B	1.5
Server1	B	1
Sink1	B	0.0

PartC – Sequences

Sequence	Sequence Type	Process Time (Minutes)
Server2	C	Random.Triangular(.5,1.2,1.6)
Sink1	C	0.0

Sequences

Sequence	Sequence Type	Process Time (Minutes)
Server1	A	Random.Uniform(.5,.9)
Server2	A	Random.Triangular(.5,1.1,1.2)
Sink1	A	0.0
Server3	B	Random.Triangular(.5,.8,1.2)
Server2	B	1.5
Server1	B	1
Sink1	B	0.0
Server2	C	Random.Triangular(.5,1.2,1.6)
Sink1	C	0.0

Properties: Sequences (Table)

General	
Name	Sequences
Description	

General
A table contains rows of data which can be used in the simulation.

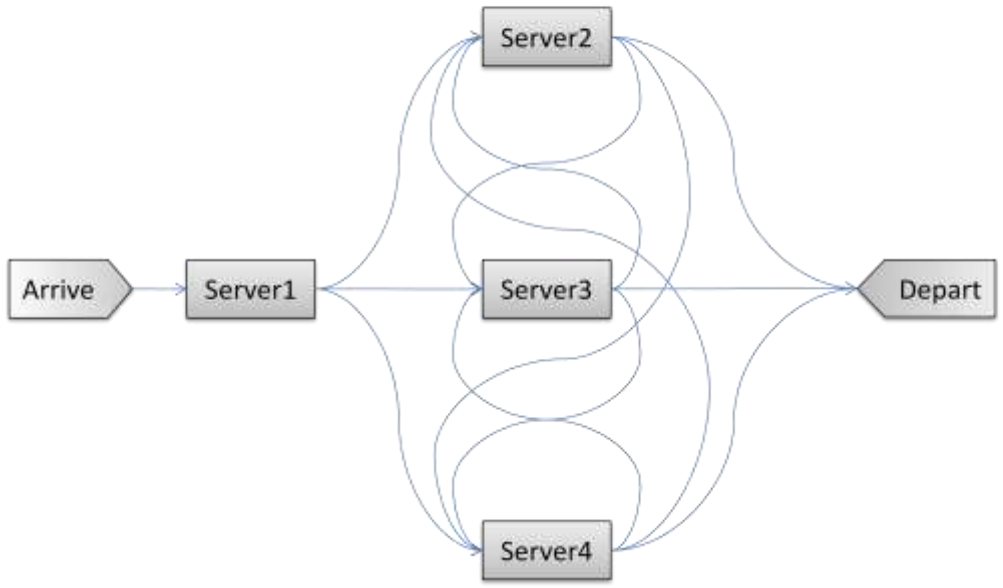
With this data schema we only need to have the entity reference a row in *JobTable*, and then it automatically has access to the corresponding sequence data in the Sequences table through the relation that has been established with the foreign key reference. For example setting a token to point to row 2 in the *JobTable* also establishes *Server3-Server2-Server1-Sink* as the routing sequence. Within the Server we reference the processing time as *Sequences.ProcessTime*, and the value is automatically selected based on both the part type and its current sequence step within its routing. For example *PartB* will use *1.5* minutes for its processing time at *Server2*.

This relational data schema has a number of advantages over our previous approach of creating a separate table for each part routing. Besides having fewer tables and indirections we can also add additional routing sequences to our model without changing the data schema. This is particularly important when importing routings from external data sources.

Example: Initializing an Array using a Table

In Chapter 3 we discussed the use of processes to make assignments to state arrays. One of the options noted for defining and initializing a state array was the [Table] option. We will now give an example where we initialize a state array with a table, and then make assignments to that array from within the model.

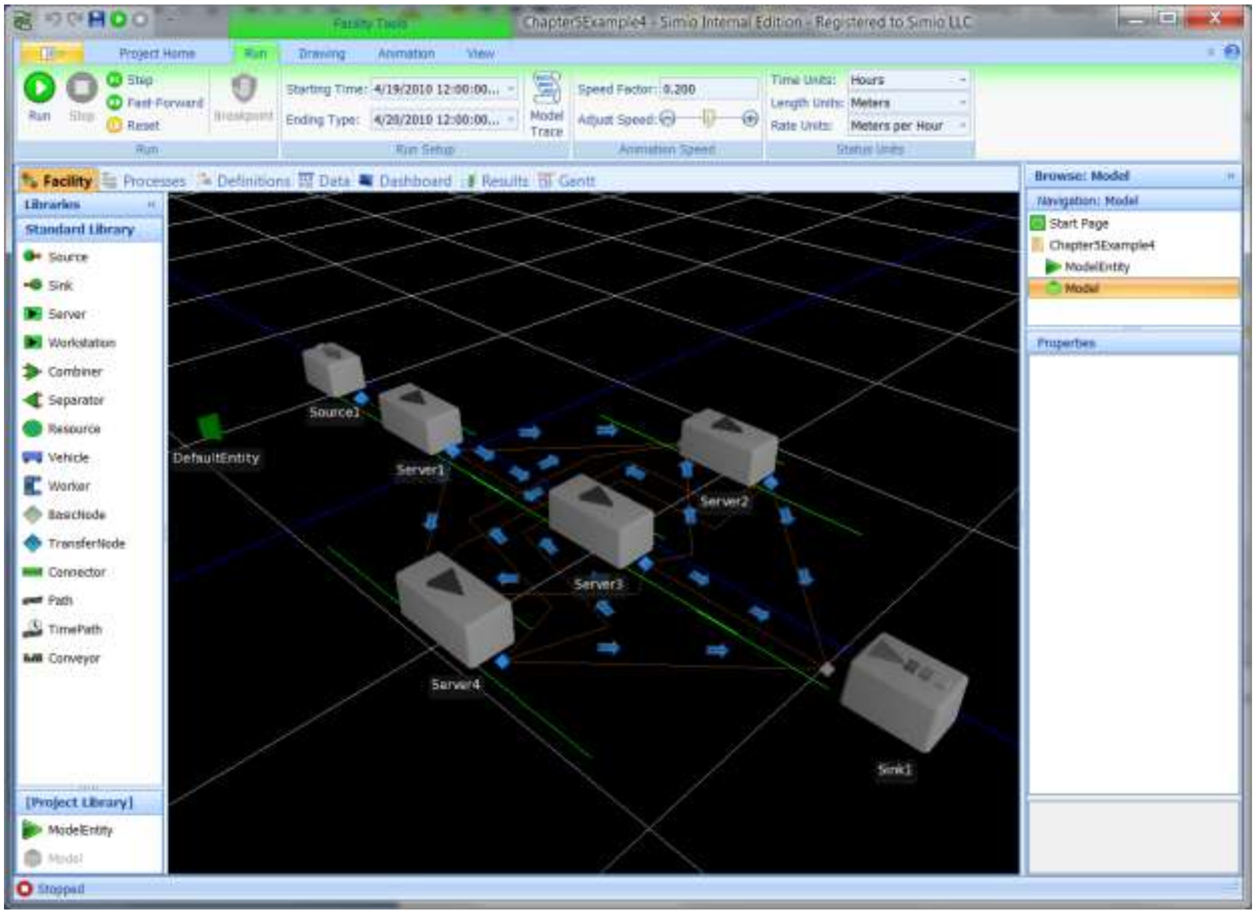
In this example we have four Server locations that are linked together by unidirectional paths as shown below. Parts always enter the system at Server1, and must visit the other three Servers in any order before departing the system. Once they have visited all four Servers they then depart the system. For example a part leaving *Server2* either proceeds to Depart (if all operations are done), or proceeds to *Server3* or *Server4*.



Whenever more than once choice is available for the next Server to visit, we want to choose the path that has been least traveled. For example if we have an option departing *Server2* to go to either *Server3* or *Server4*, we will make this choice based on a count of the number of parts that have travelled each path. We will keep this count in an array that we wish to initialize with an initial count as follows, and then bump by 1 each time we travel the path.

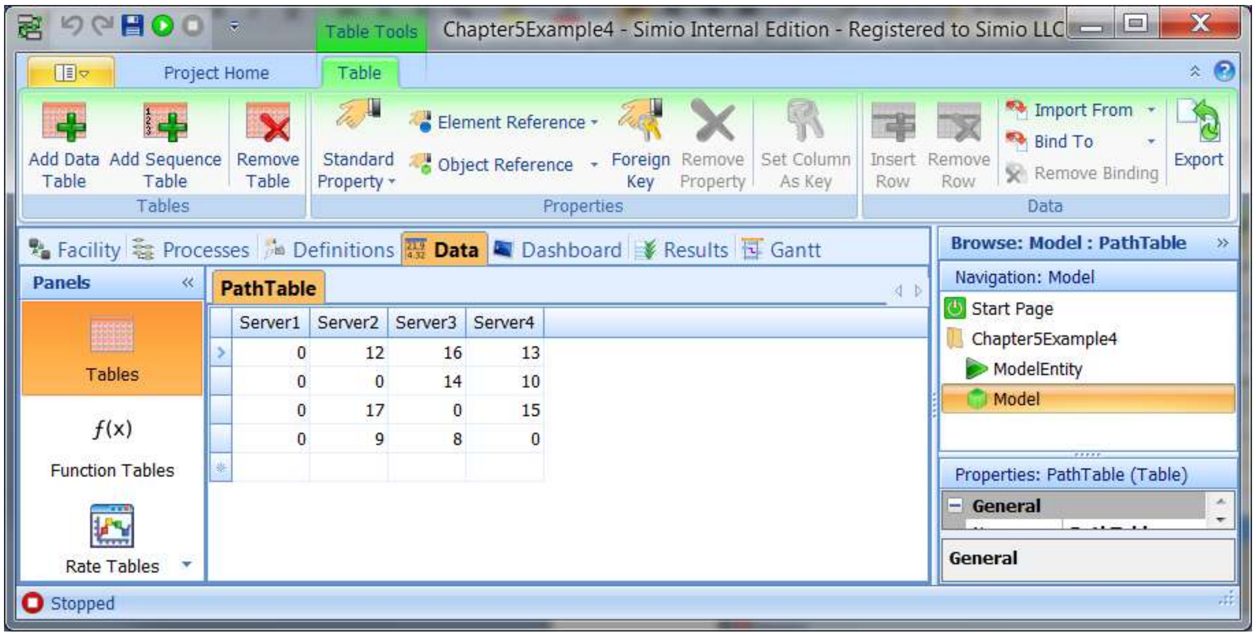
From/To	Server1	Server2	Server3	Server4
Server1	0	12	16	13
Server2	0	0	14	10
Server3	0	17	0	15
Server4	0	9	8	0

We will begin by building our facility model. We place a Source, 4 Servers, and a Sink, and then connect them with paths as shown below:



Starting Time: 4/19/2010 12:00:00...
Ending Type: 4/20/2010 12:00:00...
Speed Factor: 0.200
Adjust Speed:
Time Units: Hours
Length Units: Meters
Rate Units: Meters per Hour

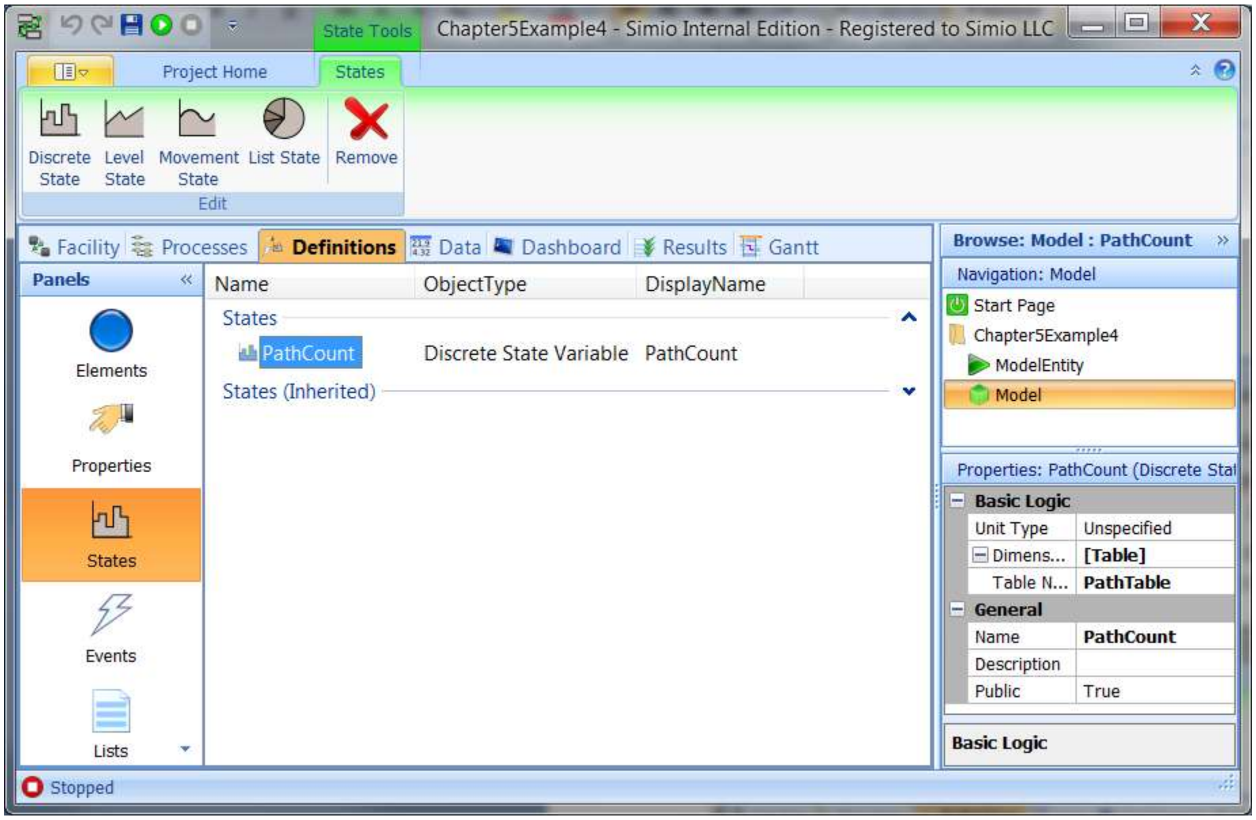
Next we will define our data table for initializing our *PathCount* state array. We add a data table named *PathTable* and create real-valued columns named *Server1, Server2, Server3*, and *Server4*, and then populate this table with counts for each travel path as follows:



PathTable

Server1	Server2	Server3	Server4
0	12	16	13
0	0	14	10
0	17	0	15
0	9	8	0

To create our state variable for our main model we click on the States panel in the Data window and then add Discrete State and rename our new state *PathCount*. We then specify the dimension as *[Table],* with the *TableName* specified as *PathTable*. Note that this will automatically dimension our *PathCount* state array and initialize it with the values given in the table. If we were to bind the *PathTable* to an external Excel spreadsheet we could then edit the initial counts directly in Excel.



Name	ObjectType	DisplayName
States		
PathCount	Discrete State Variable	PathCount
States (Inherited)		

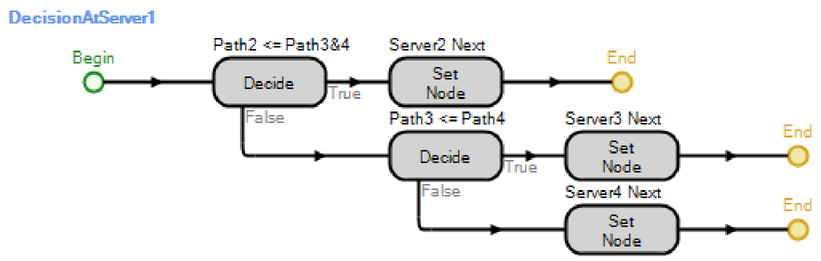
Properties: PathCount (Discrete Stat

Basic Logic	
Unit Type	Unspecified
Dimens...	**[Table]**
Table N...	**PathTable**
General	
Name	**PathCount**
Description	
Public	True

Basic Logic

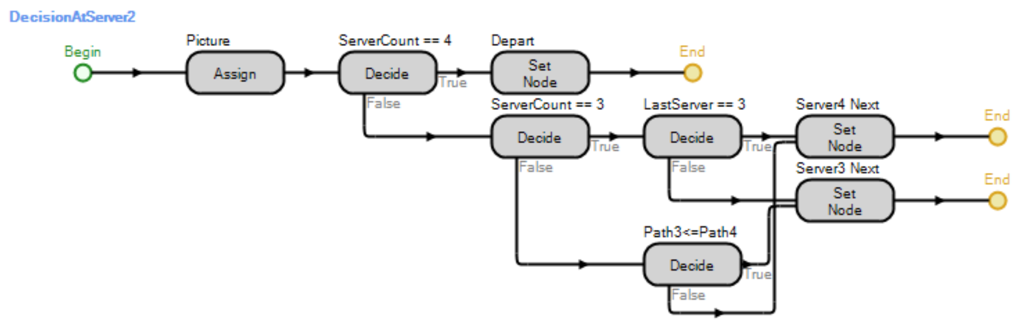
When departing *Server1* we will make our select our next destination based on the smallest current count for the three outgoing paths using the following process logic in the Output node at *Server1*. If the path count from Server1 to *Server2* is less than the current count to both *Server3* and *Server4* we select *Server2*, otherwise we select between *Server3* and *Serve4* based on the smallest path count. We enter the expression for Path2 <= Path3&4 as:

PathCount[1,2] <= Math.Min(PathCount[1,3], PathCount[1,4]).



To support the destination selection logic at Servers 2, 3, and 4 we will keep a count on the number of Servers visited by each part, as well as the index of the last Server visited. We select our *ModelEntity* and click on the States panel in its Definition window and add a Discrete State named *LastServer*. For the number of Servers visited we will make use of the existing *Picture* state variable on *ModelEntity*. We will bump this value by 1 each time a the part leaves Server 2, 3, or 4, and then use a Green, Red, Blue, and Yellow entity symbol animate the number of Servers that have been visited by each part.

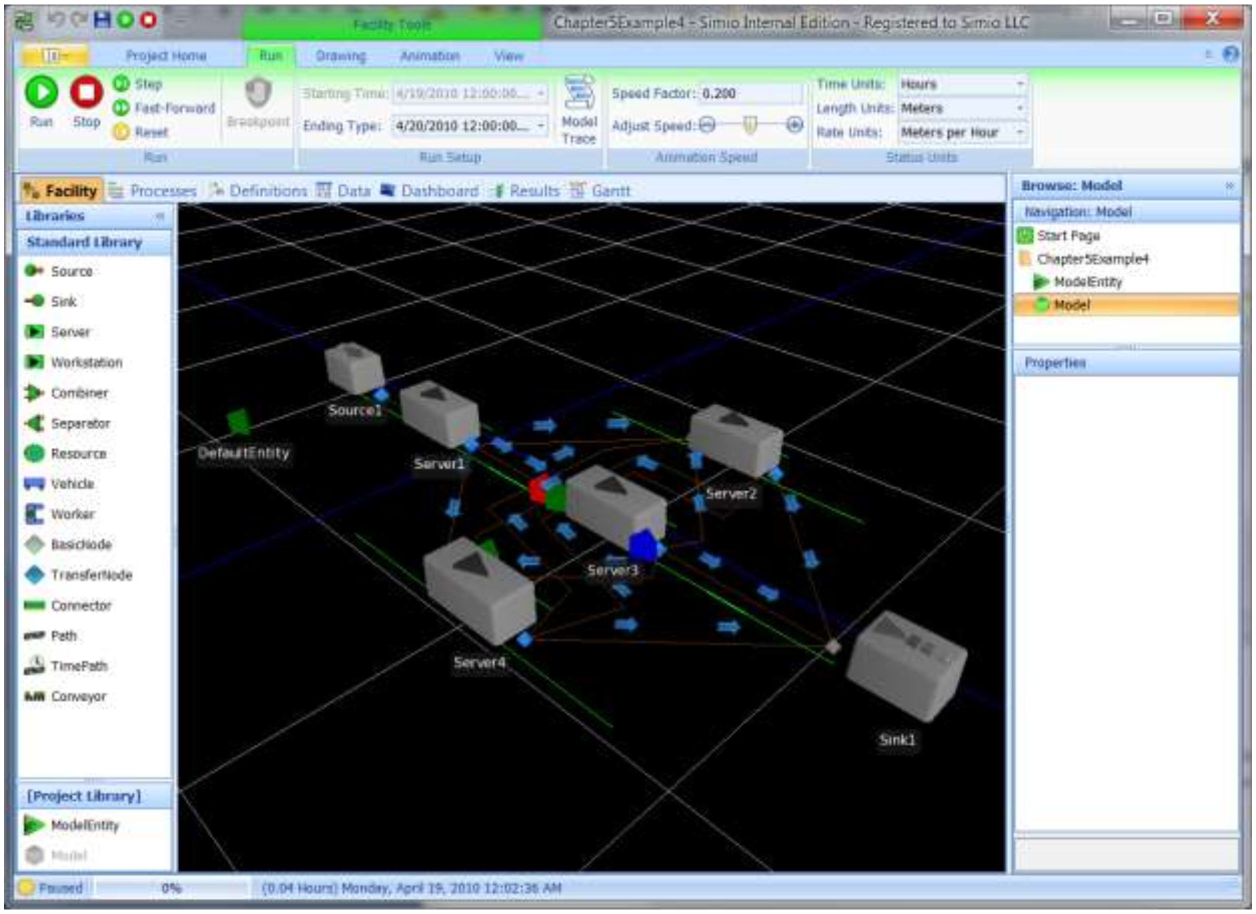
When departing Server2 we will use the following process logic.



We first increment the Picture state variable and then check if the server count is equal to four. Note that this expression is entered as *ModelEntity.Picture == 3* since we are using the Picture state for a dual purpose: to set the zero-based symbol index, and to track number of servers completed (not counting Server 1). The expression for LastServer == 3 is entered as *ModelEntity.LastServer == 3*.

If the server count for this part is 4 (i.e. *ModelEntity.Picture == 3*) we go straight to Depart. Otherwise if the server count is 3 we select between *Server3* and *Server4* to avoid revisiting the same Server again as our last Server. Otherwise we have yet to visit either *Server3* or *Server4* so we select between them based on the travel path count. Note that this logic will ensure that we visit each Server exactly once. We define similar logic for selecting our next destination at *Server3* and *Server4*.

We add the decision processes to the Entered add-on process for the output node on each of the Servers. We also add a small assignment process to each of the Exited add-on processes on the output nodes for *Server2*, *Server3*, and *Server4* to update *ModelEntity.LastServer* to 2, 3, and 4 respectively. Finally we add a small assignment process for the Entered process trigger to each of the paths connecting the four servers to update the path count. For example the path connecting *Server2* to *Server3* we increment *PathCount[2,3]* by 1. We are now ready to run which produces the following animated model.



Summary

This chapter has reviewed the basic concepts for creating data driven models. The table features of Simio can be used to create models that obtain their input data from Excel spreadsheets and other external data sources making it very easy to manipulate the data for the model.

Chapter 6: Object Definitions

Overview

The Standard Library that we have been using up to this point is just one of many possible libraries that you can use to build your models. You can build libraries of objects for your own purposes, or build libraries to share across your enterprise. You can also build commercial libraries that you market and sell to others. In this chapter we will examine the basic concepts and methods for building your own object definitions, and sharing them with libraries.

One of the basic principles of Simio is the notion that any model can be an object definition. Models are used to define the basic behavior of an object. It is very easy to take a model that you have developed and then “package” it up for someone else to use as a building block for their models. It is also very easy to build sub-models within own project, and then build your model using these sub-models as building blocks.

The material we will be discussing here is an extension of the ideas we presented in Chapter 4 on process modeling. In that chapter we learned how to use processes to extend the basic functionality of a specific object instance, without altering the core behavior of the object definition. In this chapter our focus will be on either modifying or extending the core behavior of an object definition - thereby changing the behavior of all instances of that object – or on building new objects from scratch.

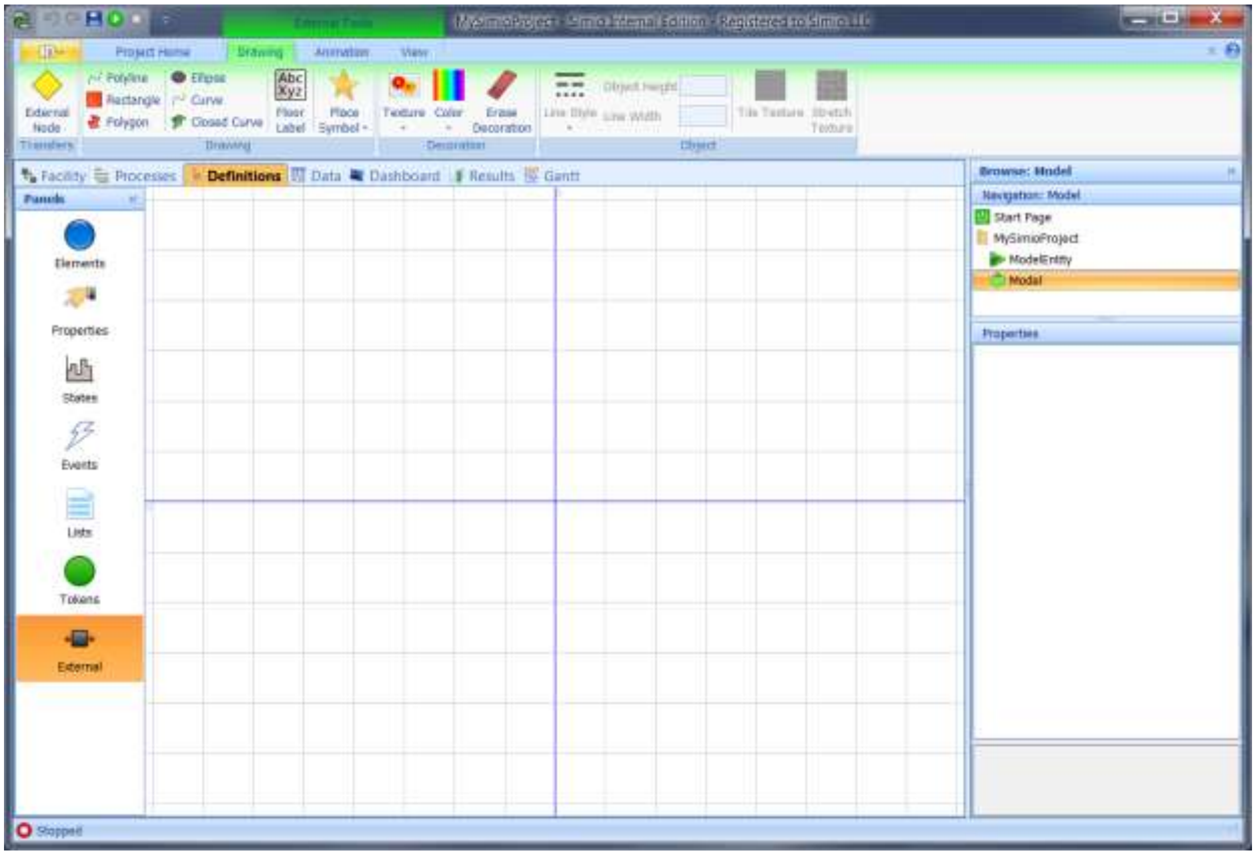
Basic Concepts

An object definition has five primary components: **properties**, **states**, **events**, **external view**, and **logic**. The properties, states, events, and external view are all defined in the Definitions window for a model. The logic is defined in the Facility and Processes window for the model.

We began using model properties back in Chapter 1 to create properties that were referenced in our model and could be used for experimentation. These same properties are used to define inputs for a model when used as an object definition. Model properties provide inputs to model logic and remain static during the run. States are used to define the current state of the object. Anything that can change during the execution of the simulation is represented in the object as a state. Events are logical occurrences at an instant in time such as an entity entering a station or departing a node. Objects may define and fire their own events to notify other objects that something of interest has happened. The external view is a graphical representation for instances of the object. The external view is what someone sees when they place the object in their model. The logic for the object is simply a model that defines how the object reacts to events. The logic gives the object its behavior. This logic can be built hierarchically using existing objects, or defined with graphical process flows.

External View

The external view is a graphical representation for instances of a fixed or dynamic object. The external view is not used for nodes or links. The external view is defined by clicking on the External panel in the Definitions window for a model as shown below:



The external view is what a user sees when they place an instance of the object in their model. The graphics for the external view can be composed of symbols from the symbol library or downloaded from Google Warehouse, as well as static graphics drawn using the drawing tools on the Drawing ribbon. In addition the view may contain attached animation components that are placed into the view from the Animation window. These animation components include animated queues, status labels, plots, pie charts, linear/circular gauges, and buttons. Note that in the case of dynamic objects (i.e. entities) these animated objects are carried by each dynamic object in the system. For example an entity could carry a status label showing the value of one of its states, or a button that when clicked by the user causes some action to take place.

When you build a new fixed object you typically provide associated input/output nodes for the object so that dynamic entities may enter and/or leave your fixed object. For example a Server object has associated node objects for input and output. The characteristics of these associated objects are also defined in the external view of the object by placing external node symbols in the external view using the Drawing ribbon. Note that these are not node objects but symbols identifying the location where associated node objects will be created when this object is placed.

When you place a node symbol in the external view you must also define its properties. The *Node Class* specifies the type of node that should be created. The drop list will give you a choice from all available node definitions which will include *Node* (empty model), *BasicNode* (simple intersection), and *TransferNode* (intersection with support for setting destination and selecting transporters to ride), as well as any other node definitions that you have loaded as libraries or are defined in your project. In the case of the Standard Library the *BasicNode* class is always used for input nodes, and the *TransferNode* is used for output nodes. The *Input Logic Type* specifies how arriving entities attempting to enter this object are to be handled by this object. The *None* option specifies that entities are not permitted to enter. The *ProcessStation* option specifies that the arriving entity may enter at a specified station, which fires a station entered event that can be used to trigger process logic. This is used when defining the object logic using a process model. The *FacilityNode* option specifies that the arriving entity is to be sent to a node inside the facility model for the object. This option is used for defining object logic using a facility model. In the *General* section the *Name* for the node symbol is specified. This node symbol name is used to create the name of the associated node object that is created at this symbol location when this object is instantiated using the format *NodeSymbolName@ObjectName*. For example if the symbol name is *Input* and the object name is *Lathe*, the associated object that is automatically created is named *Input@Lathe*. In the Standard Library the input node symbols are named *Input* and output node symbols are named *Output*.

Model Logic

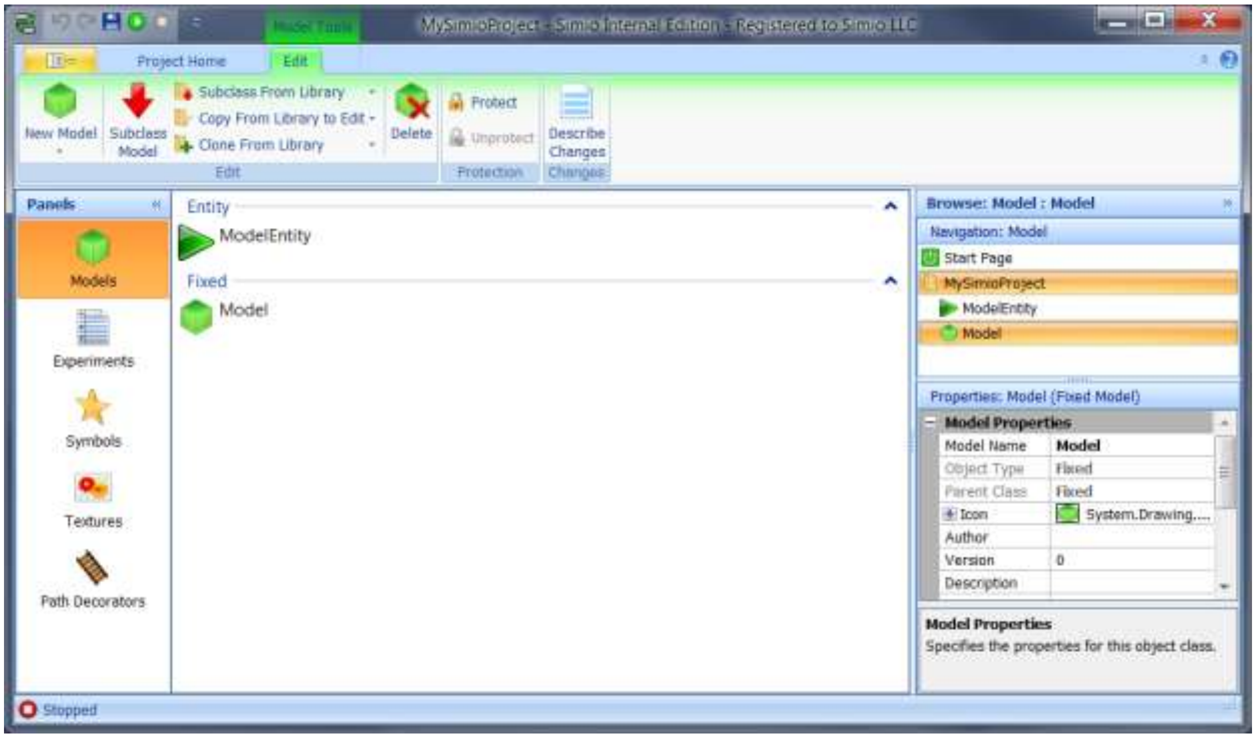
The logic for a fixed object definition is defined using a facility and/or process model, as determined by the *Input Logic Type* on the node symbols. In the case of entities, transporters, nodes and links there are no node symbols and hence these models are typically built using process logic.

Whenever you have built a model of a system it represents the logic component of an object definition. You can typically turn any model into a useable object definition by simply adding some properties to supply inputs to the model, along with an external view to provide a graphical representation for the object along with nodes that allow entities to enter and exit the model.

There are three approaches to defining the model logic for an object. The first approach is to create your model hierarchically using a facility model. This approach can also be combined with the use of add-on processes to define custom behavior within the facility objects. This approach is typically used for building up higher level facility components such a work center comprised of two machines, a worker, and tooling. The second and most flexible approach is to create the object definition behavior from scratch using a process model. This is the approach that was used to create the Standard Library. The third approach is to sub-class an existing object definition and then change/extend its behavior using processes. This approach is typically used when there is an existing object that has behavior similar to the desired object, and can be “tweaked” in terms of property names, descriptions, and behavior to meet the needs of the new object.

The concept of sub-classing an object definition is analogous to the concept of sub-classing objects in a programming language. The basic idea is that the new object definition that you are building inherits its properties, states, events, and logic from an existing object definition. The sub-classed object will initially have the same properties and behavior of the original object, and if the original object definition is updated, then the sub-classed object will inherit the new behavior. However after sub-classing you can then hide or rename the inherited properties, selectively override portions of the process logic that is inherited, or add additional processes to extend the behavior. For example you might create a new object definition named *MRI* that is sub-classed from Server and incorporated into a library for modeling healthcare systems. You might hide some of the normal Server properties (e.g. *Capacity Type*), and rename others (e.g. rename *Process Time* to *Treatment Time*). You might also replace the normal internal process that models a failure by a new process that models the failure pattern for an *MRI*, while continuing to inherit the other processes from the Server.

To sub-class an object definition, select the Project in the navigation window, and then select the Models panel.



Model Properties	
Model Name	Model
Object Type	Fixed
Parent Class	Fixed
Icon	System.Drawing....
Author	
Version	0
Description	

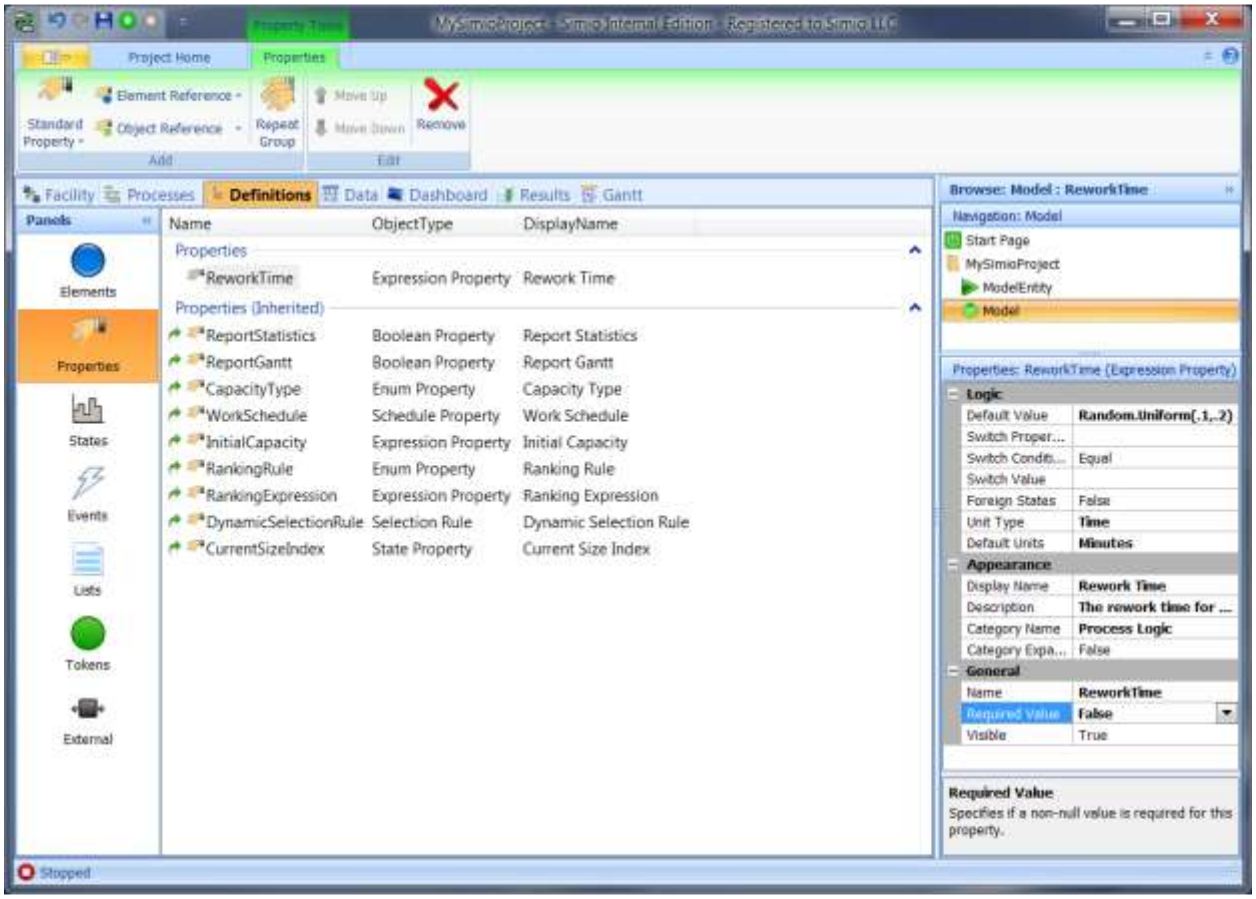
Model Properties
Specifies the properties for this object class.

The Edit ribbon lets you add a new blank model, create a sub-class of the selected model, or create a sub-class from an object definition from a library. You can also sub-class a library object using the right-click menu on the library object definition from within the Facility window. You can also create a copy of a library object without sub-classing. Note that in this case the newly created object definition is copy of the library object, but does not inherit its behavior. Hence if the original object definition is changed the copy is not affected. In contrast with a sub-classed object definition changing the original will change the behavior of the sub-classed object since it inherits process logic from its base object definition. You can also protect an object definition with a password. In this case the password is required to view or change the internal model for the object.

The model properties include the *Model Name*, *Object Type* (fixed, link, node, entity, or transporter), *Parent Class* (from which this object was sub-classed), *Icon* for displaying the model, along with the *Author*, *Version* number, and *Description*. The properties also include two flags for specifying if the object has capacity that can be seized and released as a resource, and if the object can be run as a model or only used as a sub-model within other models.

Properties, States, and Events

Whenever you create an object definition you inherit properties, states, and events from the base object class and you can add new members as well. You can view the inherited properties, states, and events in the Definitions window for the model. The inherited and new members are placed in separate categories that can be independently expanded and collapsed. The following shows the Properties panel for a model type Fixed with a single new property named *ReworkTime*. Note that this property can be referenced by both the objects and process flows within the model.



Name	ObjectType	DisplayName
Properties		
ReworkTime	Expression Property	Rework Time
Properties (Inherited)		
ReportStatistics	Boolean Property	Report Statistics
ReportGantt	Boolean Property	Report Gantt
CapacityType	Enum Property	Capacity Type
WorkSchedule	Schedule Property	Work Schedule
InitialCapacity	Expression Property	Initial Capacity
RankingRule	Enum Property	Ranking Rule
RankingExpression	Expression Property	Ranking Expression
DynamicSelectionRule	Selection Rule	Dynamic Selection Rule
CurrentSizeIndex	State Property	Current Size Index

Properties: ReworkTime (Expression Property)

Logic	
Default Value	Random.Uniform(.1,.2)
Switch Proper...	
Switch Condit...	Equal
Switch Value	
Foreign States	False
Unit Type	Time
Default Units	Minutes
Appearance	
Display Name	Rework Time
Description	The rework time for ...
Category Name	Process Logic
Category Expa...	False
General	
Name	ReworkTime
Required Value	False
Visible	True

Required Value
Specifies if a non-null value is required for this property.

The characteristics of *ReworkTime* are shown in the Property window, and include the *Default Value, Unit Type/Default Units, Display Name, Description, Category Name*, and flags specifying if this is a *Required Value* and if this property is *Visible* to the user. The characteristics also include a *Switch Property Name, Switch Condition,* and *Switch Value*. These can be used to hide or show a property based on the value the user specifies for another property. For example you might have property *Y* show only if the user sets property *X* to value greater than 0. This lets you dynamically configure the Property window based on user inputs.

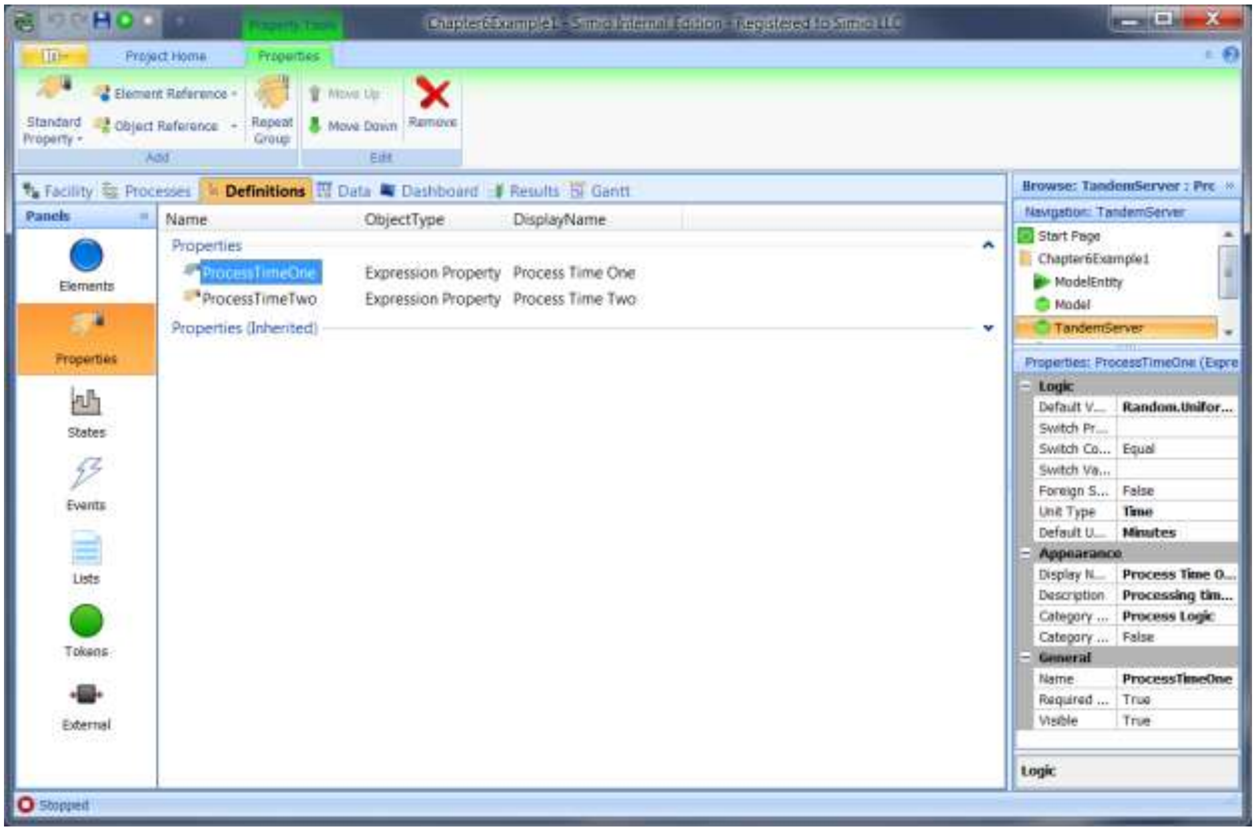
In the case of an inherited property you can change the *Visible* flag along with the *Default Value, Display Name, Description,* and *Category*. Hence you can hide properties or change their general appearance.

Although you can add additional states and events to a model you cannot rename or hide inherited states and events.

Example: Tandem Server

In this example we are going to build a new object definition for a tandem server comprised of two Standard Library Servers in series, with a Connector in between. The first Server has a capacity of one and has no output buffer. The second Server also has a capacity of one and has no input buffer; hence the second Server will block the first Server whenever it is busy. The object has two properties that specify the processing time on each of the two servers. The object also animates the entity in process at each Server, as well as animated pie charts for the resource state of each Server.

Starting with a new project add a new fixed model from the Project Home ribbon and rename this new model *TandemServer*. Select the *TandemServer* as the active model and place two Servers connected by a Connector its Facility window. Set the output buffer for Server1 to zero, and the input buffer for Server2 to zero. Now in the Properties panel of the Definitions window add two new expression properties named *ProcessTimeOne* and *ProcessTimeTwo*, and set their Default Value, UnitType/Default Units, Display Name, and Category Name as shown below. Expand the inherited properties. Since the inherited properties named *CapacityType*, *WorkSchedule*, and *IntialCapacity* are not relevant for our TandemServer object, set the Visible characteristic in the General category to False to hide each of these.



Name	ObjectType	DisplayName
Properties		
ProcessTimeOne	Expression Property	Process Time One
ProcessTimeTwo	Expression Property	Process Time Two
Properties (Inherited)		

Browse: TandemServer : Prc

Navigation: TandemServer

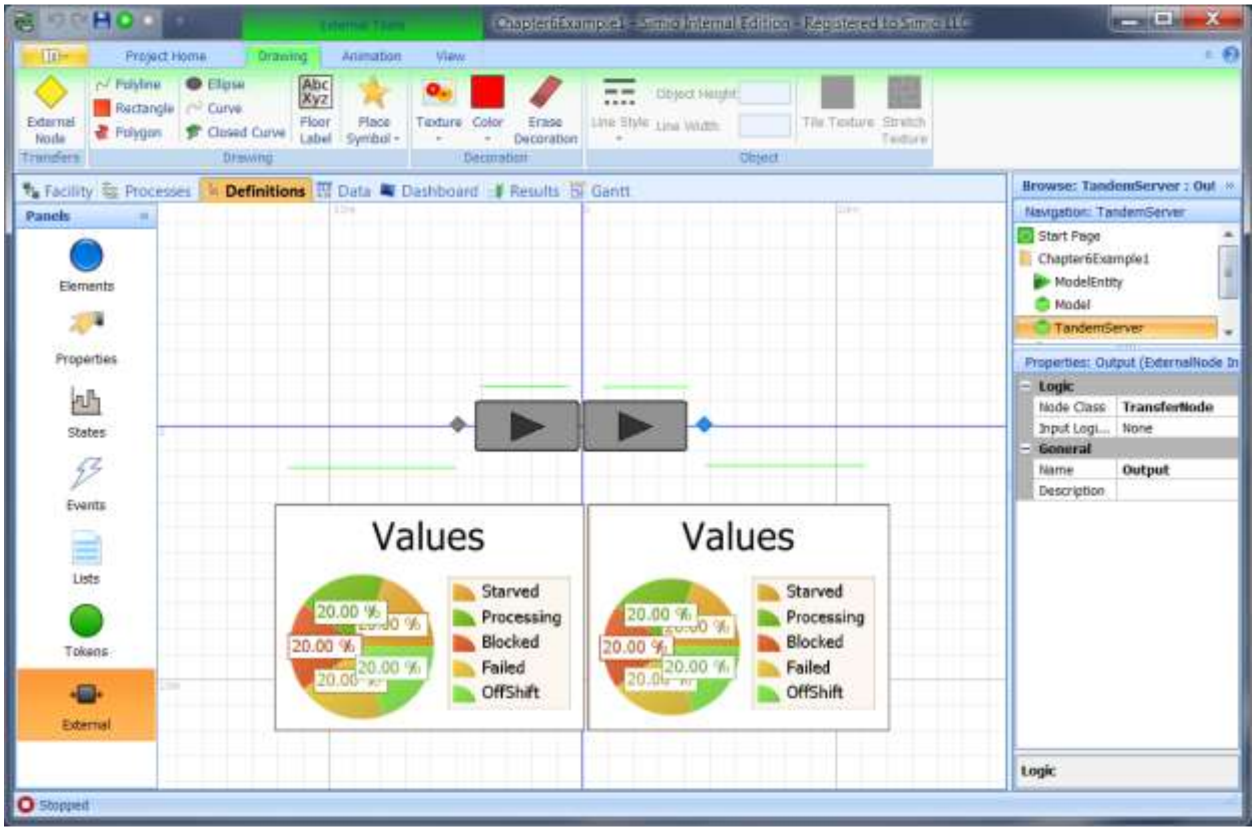
- Start Page
- Chapter6Example1
  - ModelEntity
  - Model
  - TandemServer

Properties: ProcessTimeOne (Expre

Logic	
Default V...	Random.Unifor...
Switch Pr...	
Switch Co...	Equal
Switch Va...	
Foreign S...	False
Unit Type	Time
Default U...	Minutes
Appearance	
Display N...	Process Time O...
Description	Processing tim...
Category ...	Process Logic
Category ...	False
General	
Name	ProcessTimeOne
Required ...	True
Visible	True

Logic

Now select the External panel and place two Server symbols back to back. Place an External Node on the input side named *Input*, with *Node Class* specified as *BasicNode*, *Input Logic Type* set to *FacilityNode*, and *Node* specified as *Input@Server1*. Place a second External Node on the output side named *Output*, with *Node Class* specified as *TransferNode*, and *Input Logic Type* set to *None* (no entry allowed on this side of the tandem server). Using the Animation ribbon draw animated queues for the input buffer, the two processing stations, and the output buffer, and specify the Queue States as Server1.InputBuffer.Contents, Server1.Processing.Contents, Server2.Processing.Contents, and Server2.OutputBuffer.Contents. Also add two animated pie charts specifying the *Data Type* as *ListState* and *List State* as *Server1.ResourceState* and *Server2.ResourceState*, respectively, as shown below:

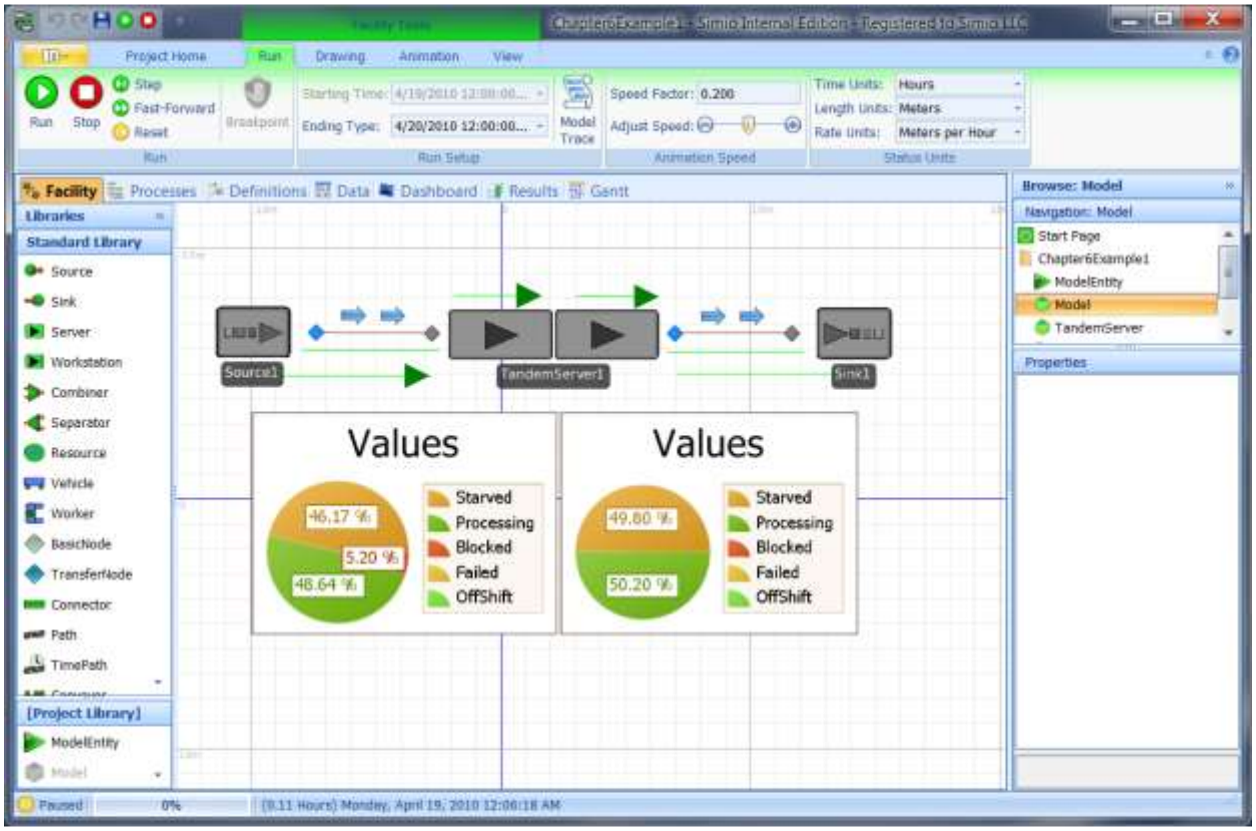


Node Class	TransferNode
Input Logi...	None
Name	Output
Description	

Note that in our external view we are sending entities arriving to the associated node that is created by the Input node symbol to the node named Input@Server1 in our facility model of the *TandemServer*. Here they will proceed through the two Servers until they reach the output node of Server2, where we want to send them back up to the associated node defined by the external node symbol named Output. To do this return to the facility model for *TandemServer* and click on the output node for Server2 and under the General category set the *Auto Transfer On Entry* flag to *To Parent External Node* and specify the *External Node Name* as *Output*. This will cause the departing entities to be sent out from the associated output node that is created for the Output symbol.

We will also edit the processing time for Server1 to be *ProcessTimeOne* and the processing time for Server2 to be *ProcessTimeTwo*. Hence these processing times are specified by our newly created properties for *TandemServer*.

We are now ready to use our new object definition. Click on our main model (Model) to make it the active model, and then place a Source, TandemServer (selected from the Project Library), and Sink, and connect them with Paths. If you click on the TandemServer you will now see our customer properties displayed in the Property window. The following shows our simple model employing our new TandemServer object in operation.



Starting Time: 4/19/2010 12:00:00...
Ending Type: 4/20/2010 12:00:00...
Speed Factor: 0.200
Time Units: Hours
Length Units: Meters
Rate Units: Meters per Hour

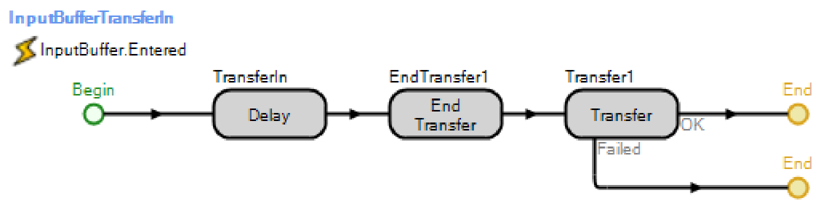
Example: A Base Lathe

In our last example we built a new object definition using a facility model. We will now do the same thing using a process model. Our new object will be a lathe that can process one part at a time. Our lathe has an input buffer for holding waiting parts, and an output buffer for parts waiting to exit to their next location.

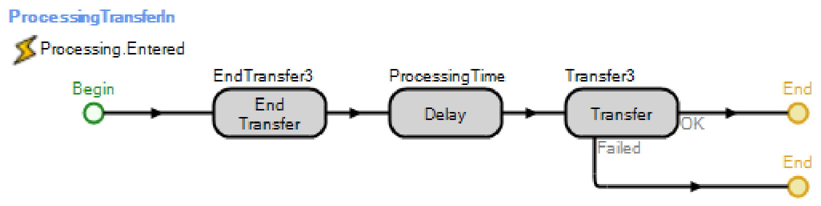
Starting with a new project (ModelEntity and Model) add a new fixed model from the Project Home ribbon and rename it *Lathe*. Make *Lathe* the active model and click on the Properties panel in the Definitions window.   We will define four new properties for our new object. Within the category named *Process Logic* we will have a *Transfer In Time* for accepting new entities into our input buffer, and a *Processing Time* for processing parts on the lathe.   Within the category named *Buffer Capacity* we will have properties named *InputBufferCapacity* (with display name *Input Buffer)* and *OutputBufferCapacity (*with display name *Output Buffer)* for specifying the buffer sizes. In addition we will hide the inherited the properties named *CapacityType, WorkSchedule*, and *InitialCapacity* since these are not relevant for our lathe object.

With these properties defined we will then add three station elements named *InputBuffer*, *Processing*, and *OutputBuffer*. Click on the Elements panel in the Definitions window and add and rename these elements. Specify the initial capacity for the *InputBuffer* as the property named *InputBufferCapacity* and the initial capacity for the *OutputBuffer* as the property named *OutputBufferCapacity*. Specify the initial capacity for *Processing* as 1.

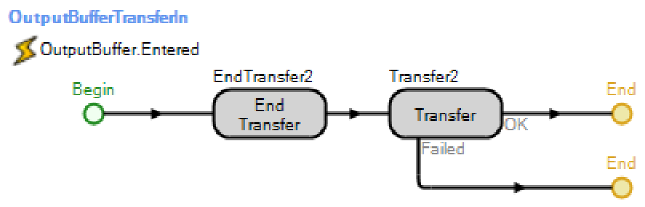
Now we will build three process flows for entering each of these three stations.   Entities will enter this object by executing the process flow for the *InputBuffer* shown below:



The token that executes this process is triggered by the *InputBuffer.Entered* event and delays by the *TransferInTime* property value before ending the transfer. The EndTransfer step signals to the outside world (perhaps a conveyor, robot, person, etc.) that the transfer is now complete. Once the transfer is complete a new transfer can begin as long as there is remaining space in the *InputBuffer* station. The token then initiates a transfer of the entity from the *InputBuffer* station to the *Processing* station which executes the following logic.

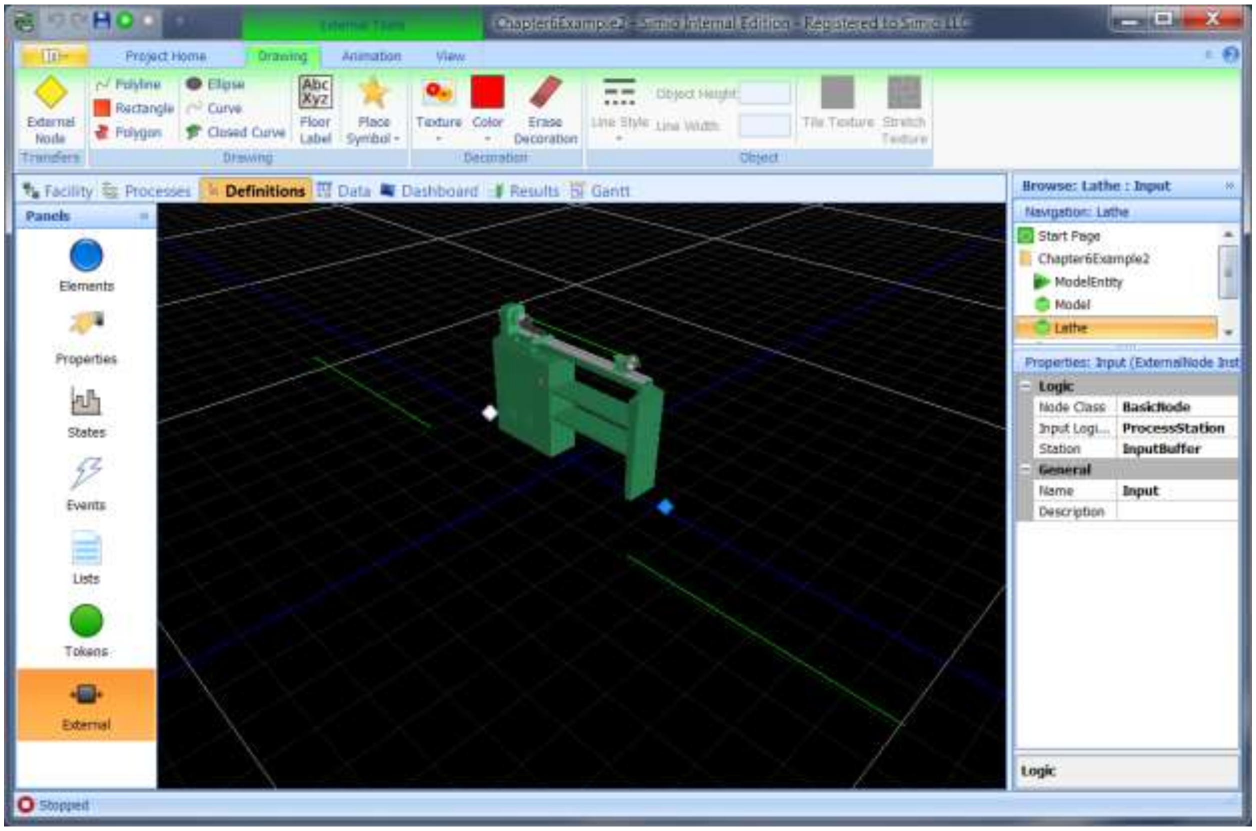


Here the token immediately ends the transfer and then delays by the ProcessingTime property value before initiating a transfer from the Processing station to the OutputBuffer station which executes the following logic.



Here the token terminates the transfer and then initiates a transfer from the *OutputBuffer* out through the associated node object that is defined by the *ParentExternalNode* named *Output* (note: we will not be able to specify this node until we have first defined it in the external view).

Next we will define the external view. Click on the External panel in the Definitions window and place a lathe symbol from the symbol library in the center of the external view, and add an external node with *Class Type BasicNode* and named *Input* on the left side of the lathe, and an external node with *Class Type TransferNode* and named *Output* on the right side of the lathe (we can now go back and specify our *ParentExternalNode* named *Output* on our *OutputBuffer* Transfer step). Specify the *Input Logic Type* on the *Input* external node as *ProcessStation*, and then select *InputBuffer* from the drop list. Note that arriving entities will transfer to the *InputBuffer* station upon arrival to the associated node object corresponding to this external node symbol. We will add animated queues for animating the InputBuffer, Processing, and OutputBuffer stations. Our external view for the Lathe is shown below:

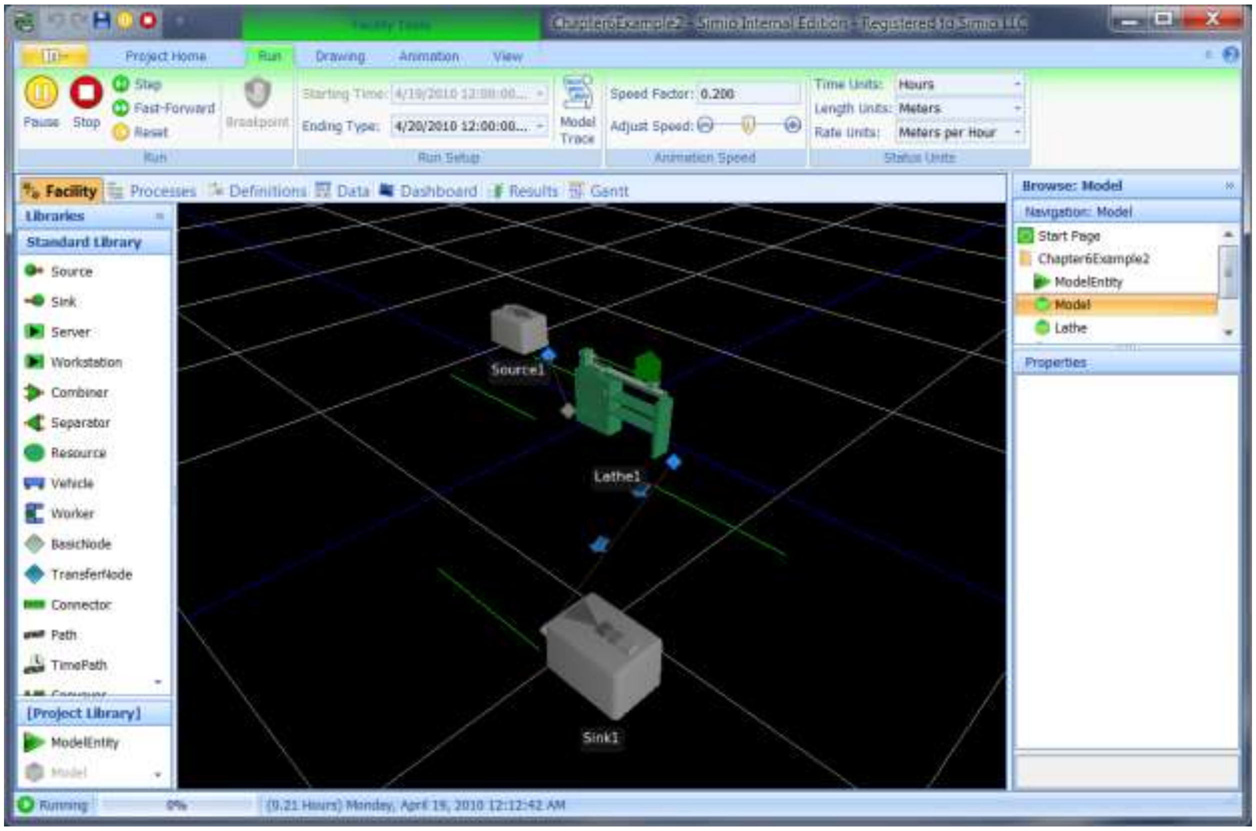


Properties: Input (ExternalNode Inst

Logic	
Node Class	BasicNode
Input Logi...	ProcessStation
Station	InputBuffer
General	
Name	Input
Description	

Logic

We are now ready to use our new object definition in a model. Click on Model in the navigation window to make it our active model and drag out a Source, Lathe (from the Project Library), and Sink, and connect them with Paths. Click on Lathe to edit its properties. You can now run the model.



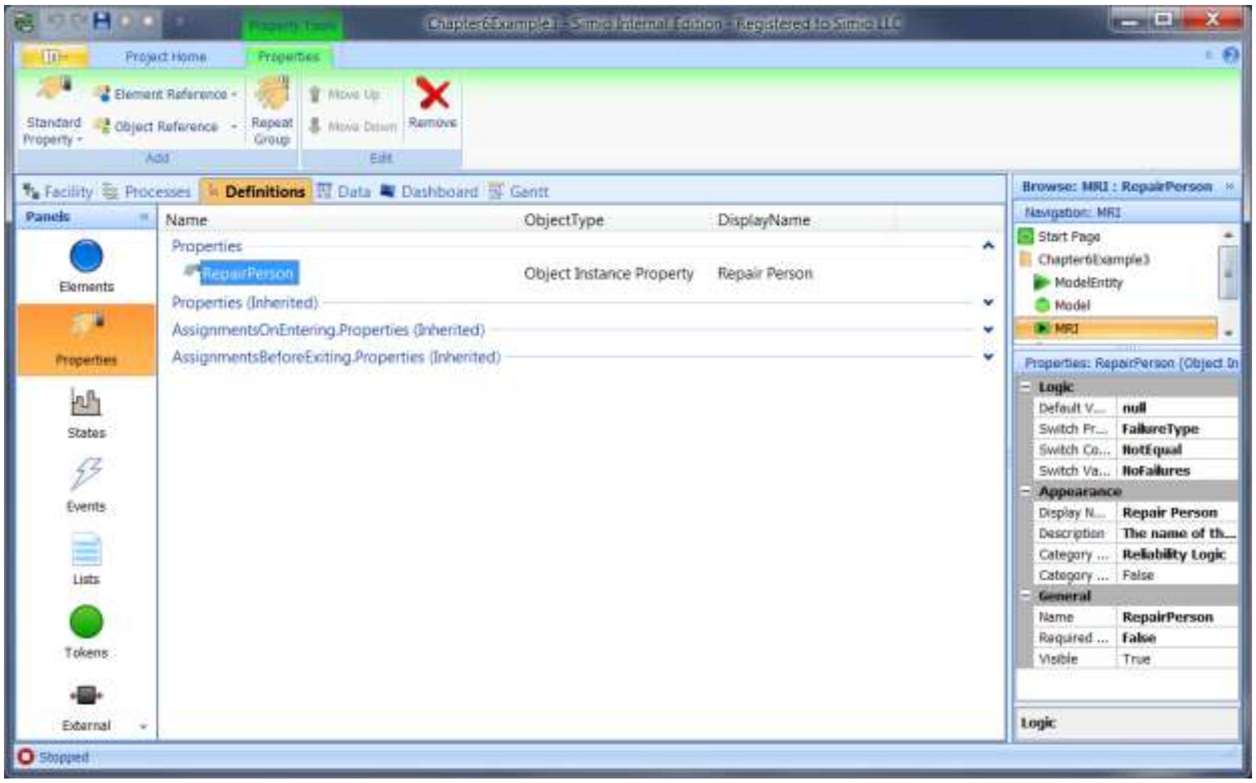
Starting Time: 4/19/2010 12:00:00...
Ending Type: 4/20/2010 12:00:00...
Speed Factor: 0.200
Adjust Speed:
Time Units: Hours
Length Units: Meters
Rate Units: Meters per Hour

Running 0% (0.21 Hours) Monday, April 19, 2010 12:12:42 AM

Example: Server with Repairman

In this example we are going to build a new object definition named MRI that is sub-classed from Server. We will hide and rename some properties, and add a new property to specify an optional repair person that is required to perform a repair on the MRI. We will then modify the repair logic to seize and release this repair person.

Beginning with a new project we right click on Server in the Facility window and select Sub-Class (we could do this same operation in the Project window). This adds a new model to our project named MyServer, which we will rename MRI. Click on MRI to make it the active model, and then click on the Properties panel in the Definitions window. Add a new object reference property and rename it RepairPerson and specify its category as Reliability Logic. Specify the Switch Property Name as Failure Type, the Switch Condition as NotEqual, and the Switch Value as NoFailures. Hence this property will not be visible if the NoFailures option is selected by the user. We will also set the Required Value flag to False for this property. This property definition is shown below:



Name	ObjectType	DisplayName
Properties		
RepairPerson	Object Instance Property	Repair Person
Properties (Inherited)		
AssignmentsOnEntering.Properties (Inherited)		
AssignmentsBeforeExiting.Properties (Inherited)		

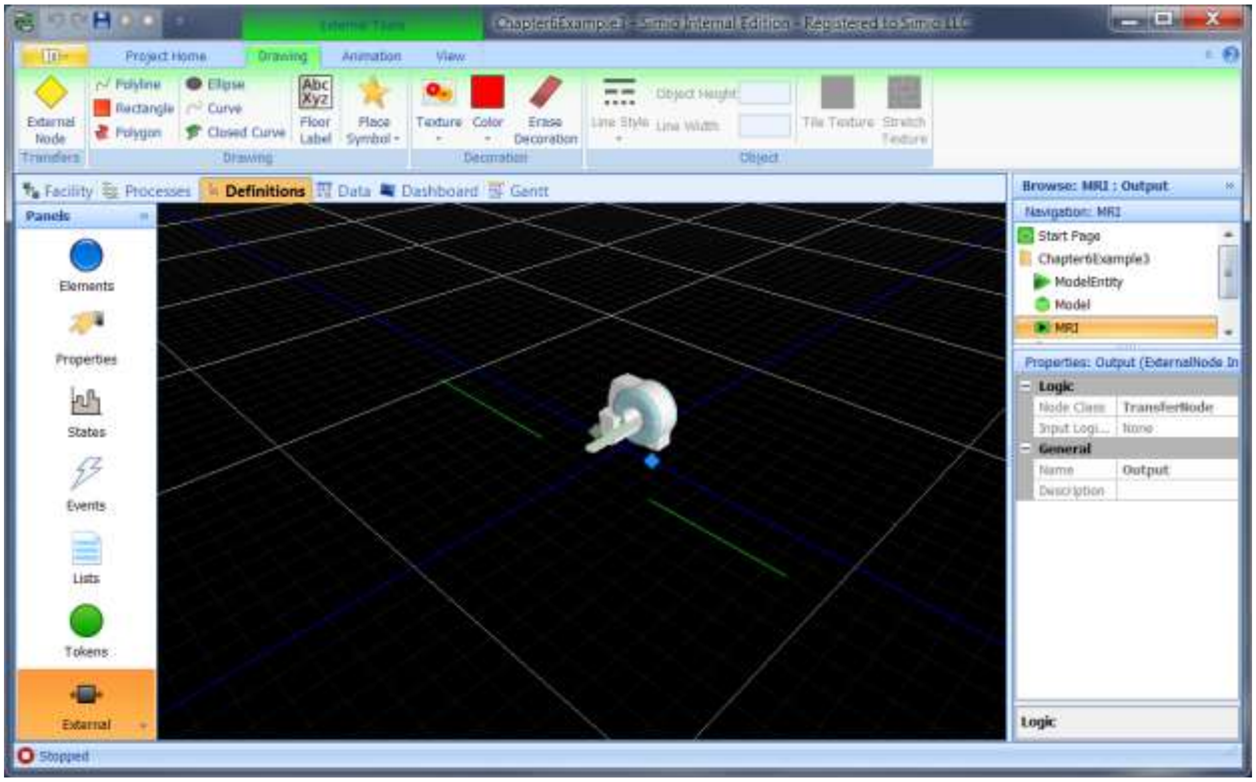
Properties: RepairPerson (Object In

Logic	
Default V...	null
Switch Pr...	FailureType
Switch Co...	NotEqual
Switch Va...	NoFailures
Appearance	
Display N...	Repair Person
Description	The name of th...
Category ...	Reliability Logic
Category ...	False
General	
Name	RepairPerson
Required ...	False
Visible	True

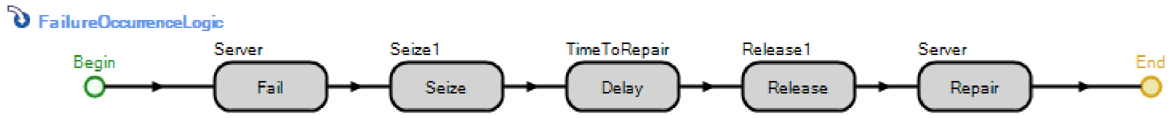
Logic

We will also hide the inherited properties named *Capacity Type, WorkSchedule*, and *InitialCapacity*, and rename the ProcessingTime property to Treatment Time, and enter a new description for this property.

Next we will define the external view for the MRI. Click on the External panel in the Definitions window, and then in the Place Symbol drop list select Download Symbol to download an MRI graphic from Google Warehouse and add animated queues for the queue *states InputBuffer.Contents*, *Processing.Contents,* and *OutputBuffer.Contents*. Note that the two external node symbols are inherited from the Server and cannot be modified.

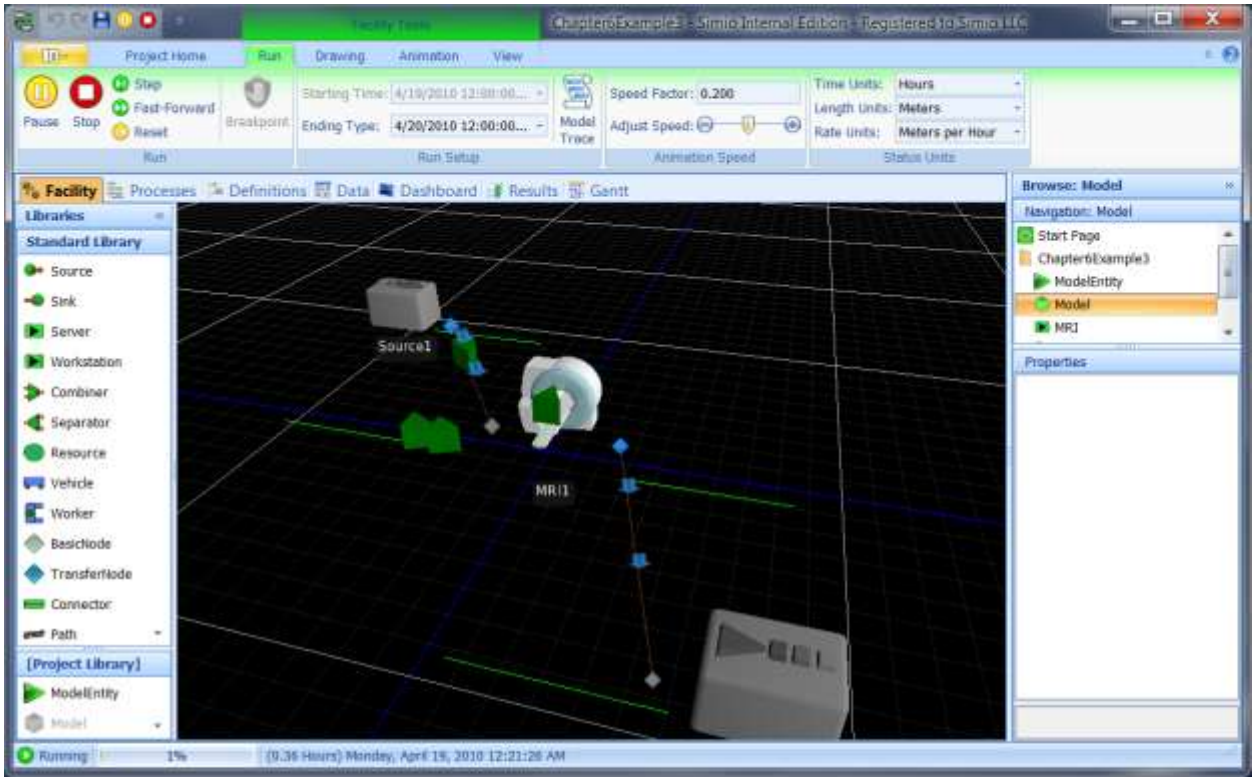


In last step we will modify the process logic that we have inherited to make use of the repair person during maintenance. Click on the Processes window to display the inherited processes from the base Server definition. Note that you cannot edit any of the processes at this point because they are owned by the Server and are inherited for use by the MRI. We will select the first inherited process in MRI named *FailureOccurenceLogic* and then click on Override in the Process ribbon. This will make copy of the inherited process from the Server for use by the MRI in place of the same process that is owned by the Server. We can then edit this overridden process in any way that we wish. We will add a Seize step immediately before the *TimeToRepair* delay, and then a Release step immediately after this delay. In both steps we will specify the *RepairPerson* property as the object to seize/release. This new process is shown below:



Notice the symbol to the left of the name indicating that this is an overridden process. We could also restore back to the original process by clicking on Restore in the Process ribbon.

We are now ready to use our new MRI object definition in a model. Click on Model to return to our main model, and drag out a Source, MRI (from the Project Library), and a Sink, and connect them with Paths. Select MRI to edit its properties and then run. The following shows this simple model in operation:



Chapter6Example3 - Simio Internal Edition - Registered to Simio LLC

Starting Time: 4/19/2010 12:00:00...
Ending Type: 4/20/2010 12:00:00...
Speed Factor: 0.200
Adjust Speed:
Time Units: Hours
Length Units: Meters
Rate Units: Meters per Hour

Running 1% (0.36 Hours) Monday, April 19, 2010 12:21:26 AM

Summary

In this chapter we have reviewed the basic concepts for building object definitions in Simio. This is a key feature of Simio because it allows non-programmers to build custom objects that are focused on a specific model or application area.

In our examples here we placed our objects from the Project Library. The other alternative is to build the object definitions in their own project and then load that project as a library from the Project Home ribbon.

With Simio you often have the choice to make between working with the Standard Library embellished with add-on processes, and creating a new library with custom logic. If you encounter the same applications over and over again it is more convenient to build custom objects and thereby avoid the repeated need for add-on processes. Of course you can also provide support for add-on processes in your own objects by simply defining a property for the process name and passing that property to an Execute step within your process.

With a bit of experience you will find object building to be a simple and powerful capability for your modeling activities.

Glossary

Allocation – Granting ownership of one or more capacity units to an object.

Assign – Defining values for State Variables

Batch – A group of entities associated with another entity (e.g. boxes loaded on a pallet)

Buffer Station – A capacity constrained location where objects wait until conditions are met to proceed to their next location.

Capacity – The number of units of a resource that are available to be seized. Once all of the units are seized, no other object can seize this object until the units have been returned. During this time the requester is placed in the Allocation Queue.

Confidence Level – A percentage used to express the how likely the Confidence Interval is to contain the true population mean. For given data, a larger Confidence Level will result in a larger the spread/Half Width

Confidence Interval – A range estimate of a response value (e.g. an estimate of WIP is (352 ± 22.7)).

Delay – The amount of time that an object suspends all future actions, usually signifying some sort of action is taking place during this time (e.g. a processing time).

Destroy – Remove an object run space from the system during a run.

Discrete Event Simulation (**DES**) – A type of simulation modeling that deals with events that happen in a chronological sequence.

Element – Things that are capable of changing state over time. For example, the number of objects inside a Server doesn't change; the number of objects in the Processing Station changes. The server just dictates how the objects get into the Station. Types of Elements include:

- Activity – Performed by an operation that is owned by an object
- Batch Logic – Used with Batch step to match multiple entities together and attach the batched group to a parent entity
- Failure – Used to define a failure mode
- Material – Used with consume and produce steps to represent using and ordering defined amounts of a material in a process
- Monitor – Watches a state variable and fires an event when there is a discrete change or if it crosses a certain threshold level
- Network – A collection of Links that certain Entities or Transporters can travel on, while others cannot. A link may be on multiple networks
- Operation – Sequence of Activities that are performed over time
- Output Statistic – An expression that can be optionally recorded at the end of each replication of a simulation
- Routing Group – Used with a Route step to route an object to a destination based on a list of candidate nodes
- State Statistic – Used to record time-persistent statistics on a state variable
- Station – Capacity constrained location where an object can reside. Examples include Processing, Input Buffer, Output Buffer, and Ride Station
- Storage – A logical queue used to create a list of one or more objects

- Tally Statistic – Tallies observational statistics that are recorded using a Tally Step
- Timer – Fires a stream of events according to a specified interval type

Entity – Part of an object model and can have its own intelligent behavior. They can make decisions, reject requests, decide to take a rest, etc. Entities have object definitions just like the other objects in the model. Entity objects can be dynamically created and destroyed, moved across a network of Links and Nodes, move through 3D space, and move into and out of Fixed objects. Examples of Entity objects include customers, parts or work pieces.

Event – A notification that can be given by one object and responded to by several. It alerts other objects that an action has occurred.

Experiment – Part of the project that is used for output analysis. The user defines one or more sets of inputs/outputs (Scenarios) and runs multiple replications to get statistically valid results from which to draw conclusions.

Half Width – Half of the confidence interval. CI = Average ± Half Width. The smaller the Half Width the smaller the variability.

Library – A collection of objects/models that can be used to create a model.

Link – Pathways for entity/transporter movement. There are four types of links:

- Connector – Used to define a non-passing pathway between two node locations where travel time is instantaneous. Entities will never actually enter, move across or exit a connector, but will always instead immediately do a node-to-node direct transfer.
- Conveyor – Represents either accumulating or non-accumulating conveyors and supports both fixed and variable spacing.
- Path – Used to define a pathway between two node locations where the travel time is determined by the path length and a traveler's speed.
- Time Path – Used to define a pathway between two node locations where the travel time is user specified.

Member – The object owned by the Parent

Model – A representation of real world object or collection of objects that interact with each other. Models are usually used to make decisions and are defined by their properties, states, events, external view, and logic.

Network – A collection of Links that certain Entities or Transporters can travel on, while others cannot. A link may be on multiple networks

Object Hierarchy:

- Object Definition – A collection of Properties, States, Events, Elements, and other characteristics that defines the logic and behavior of an object and how it interacts with other objects. Every model is an object definition that can be potentially used in another model.
- Object Instance – An object definition that is placed into Simio's Facility View. It carries unique property values to identify it and customize its behavior (e.g. an entity's target speed).
- Object Run Space – Objects that are created during a run that carry with them states to record system changes (e.g. an entity's current speed). These object run spaces refer back to the object instance for their properties and to the object definition for their logic and behavior.

Parent – The "owner" of another object

Passing – Allowing one object to travel through another object on a link.

Priority – Numeric property for all Entities used to make Ranking Rules or Dynamic Selection Rules to order how entities are to be moved throughout a model.

Process – A sequence of commands that dictate the behavior of an object. Specified graphically by placing Steps in a flow process diagram.

Project – A collection of Models and Experiments that are used to represent a system.

Property – Input parameters that are associated with the object that define exactly how the object interacts with other objects. Ex – Processing Time, Selection Rule, Priority, Transfer-In Time

PseudoRandom – Something that appears to be random, but is not. DES random number generators are PseudoRandom in that they have predictability. It repeats the same random number stream every time you press "Run" and can be used again and again, useful for testing and fixing models

Queue – A collection of objects waiting for an event to occur that will allow them to enter a station, seize an object, enter a link, etc.

Release – Freeing one or more units of the reserved object to allow seizing by other objects.

Replication – Running a scenario one time, usually run multiple replications per scenario. The more replications the more accurate the statistics.

Resource – An object that represents a system constraint and can be seized and released. Any object can be a resource. Resources may be given intelligent behavior and interaction with other objects.

Scenario – A set of input values to be run in an experiment, usually a possible future state of the system being evaluated.

Selection Weight – Property of all links that determines the likelihood of choosing that particular link as an outbound link from an object. Maybe be a simple number or a complex expression.

Seize – To reserve one or more units of an object for use by the requesting object. While an object is seized no other object can take possession of that object.

Server – An object that consists of three stations: Input Buffer, Processing, and Output Buffer. Usually represents a location that has a capacitated process.

State – Dynamic values that may change as the model executes. There are four types of states:

- Discrete State – represents a numeric value that may change instantaneously at discrete event times
- Level State – represents a variable that has a numeric value that may change continuously over time based on the value of the rate.
- List State – represents an integer value corresponding to one of several entries from a string list.
- Movement State – represents a variable that has a numeric value that may change continuously over time based on the current value of the rate and acceleration.

Step – Used to define logic within a process. Each step performs an action (such as seize, delay, decide, or wait).

Stochastic Process – A process whose behavior is non-deterministic, meaning that there is randomness in the process.

Token – Executes the steps in a process flow. A Token may have one or more user defined states that carry information from step to step.

Transporter – A transporter object is a special type of entity that can pickup entity objects at a location, carry those entities through a network of links or free space, and then drop the entities off at a destination.

Validation – Determining if the model is an accurate representation of the real system – if the model's output matches the real system sufficiently to meet the model objectives.

Variability – A measure of how spread the observed data values are. A key cause of variability is the randomness incorporated into typical simulation models.

Vehicle – A transporter object that represents a machine. A vehicle has the possibility of failures representing breakdowns.

Verification – Determining if the model is built correctly - i.e. with the correct input logic, parameters, and values

Worker – A transporter object that represents a human. A worker has the ability to follow a work schedule.

Technical Support and Resources

Technical Support

The best way to get support is to contact us on-line at Simio Support.

(http://simio.devsuite.net/scripts/texcel/CustomerWise/CLogin.dll?ProjectID=20)

You will be able to immediately search the knowledgebase for common problems and commonly requested information. In addition, registered users can submit and track support requests (incidents) and suggestions for enhancements.

You can also email our support staff using support@simio.com or call us at +1-412-528-1576 or toll free at 1-877-297-4646.

You will need to know your **Simio Version Number** which can be found in the middle of the Simio start page. Although the complete number is 7 digits long (x.xx.xxxx), you will generally only need the first 3 digits, for example 3.44.

Simio User's Forum

You will find the Simio User's Forum at http://www.simio.com/forums. Here you will find more product information, a place to post questions, and the opportunity to engage in discussions with other users and the Simio team.

We encourage you to also join the **Simio Insiders** group. This has been established to let you become an important part of our process; essentially an extension to our team. Please visit our simulation community resources web page (http://www.simio.com/community.html) for additional information.

More Information

Please consult the **Start Page** of the Simio software for a description of more available resources and how to contact us with ideas, questions, or problems.

While Simio includes comprehensive help available at the touch of "F1" in the product, if you prefer a printable version, you will find a link to the **Simio Reference Guide.pdf** on the Start Page. And you will find a link to our increasing number of **Training Videos**.

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