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Arena® Basic

A·B *Allen-Bradley* · *Rockwell Software*

**Rockwell
Automation**

Contents

1 Welcome to Arena Basic Edition

What is Arena Basic Edition?

Arena Basic Edition software lets you bring the power of modeling and simulation to business process improvement. It is designed primarily for newcomers to simulation and serves as an introductory product and foundation to the rest of the Arena product family. Typically, any process that can be described by means of a flowchart can be simulated with Arena Basic Edition.

Arena Basic Edition is most effective when analyzing business, service, or simple (non-material-handling intensive) manufacturing processes or flows.

Typical scenarios include:

- Documenting, visualizing, and demonstrating the dynamics of a process with animation

- Predicting system performance based on key metrics such as costs, throughput, cycle times, and utilizations

- Identifying process bottlenecks such as queue build ups and over-utilization of resources

- Planning staff, equipment, or material requirements

In addition to the Arena Basic Edition, Rockwell Automation offers a full suite of products to provide enterprise-wide simulation, optimization, and 3D model animation.

Intended audience

The Arena Basic Edition is designed for business consultants, business analysts, and engineers. It can be widely deployed as a desktop tool and can serve as a natural extension to those who use various flowcharting packages such as Visio® to document business processes.

We assume that you are familiar with the basic concepts and terms used in these types of systems. You are interested in improving business or manufacturing productivity and are responsible for evaluating and predicting the impact of proposed strategic and tactical changes to help improve performance. A familiarity with computers and the Microsoft® Windows® operating system is assumed. A familiarity with the concepts and terms used in simulation is also helpful.

Where can I go for help?

Our commitment to your success starts with the suite of learning aids and assistance we provide for Arena. Whether you're new to simulation or a seasoned veteran putting a new tool to use, you'll quickly feel at home with the Arena Basic Edition.

Reference the user's guides

The documentation set includes this manual, *Arena Basic Edition User's Guide*, which covers the product basics in an easy, "click-by-click" tutorial for modeling and analyzing a discrete manufacturing process. In addition, the *Variables Guide* is a separate reference booklet providing complete descriptions of Arena variables found in the Arena product templates.

DOCUMENT CONVENTIONS

Throughout the guides, a number of style conventions are used to help identify material. New terms and concepts may be emphasized by use of italics or bold; file menu paths are in bold with a (>) separating the entries (e.g., go to **Help > Arena Help**); text you are asked to type is shown in Courier Bold (e.g., in this field, type `Work Week`), and dialog box and window button names are shown in bold (e.g., click **OK**).

Explore our examples

Arena is accompanied by a number of sample models that illustrate many of the commonly used approaches for capturing the essence of manufacturing processes. Examples are provided for both job shop and flow shop environments. For a description of and list of Arena's examples, go to **Help > Arena Help**. On the **Contents** tab, choose **Model Building Basics**, and then select **Viewing Arena Example Models**.

Get help

Online help is always at your fingertips! Arena incorporates the latest in help features, including *What's This?* help that displays a brief description of fields in dialogs, context-sensitive help on menu and toolbar buttons, and a help button on each of Arena's modules. Just refer to the Arena help table of contents and index for a list of all help topics.

Use the Smarts library

As you craft models of your own manufacturing processes, use our Smarts library to explore how to best use Arena. This suite of tutorial models covers topics ranging from modeling resources to animation techniques. The library is organized into categories to help you find the right model with ease. When you're wondering how to take the next step in your model, browse the Smarts library for a ready-made solution. For a list of categories and their related Smarts, go to **Help > Arena Help**. On the **Contents** tab, first click **Model Building Basics**, and then **Learning Arena with Smart Files**.

Access the Arena Symbol Factory

Arena animations can be enhanced using Arena Symbol Factory's extensive library of symbols. These symbols can be used for entity, resource, transporter, or global pictures or as graphic symbols within a model window. You can copy these symbols directly to the Arena model window, add them to your own libraries (*.plb* files), or add them to any of the Arena picture library files.

Get phone support

Rockwell Automation provides full support for the entire Arena family of products. Questions concerning installation, how modules work, the use of the model editor, and the use of the software are handled by technical support.

ARENA TECHNICAL SUPPORT INCLUDES:

- (for users on active maintenance) a technical support hotline and e-mail address staffed by full-time, experienced professionals
- help with installation problems or questions related to the software's requirements
- troubleshooting
- limited support regarding the interaction of Arena with other programs
- support of the Arena Object Model, which is used in Microsoft Visual Basic for Applications

If you call the support line (1.440.646.3434), be at your computer and be prepared to give the following information:

- the product serial number
- the product version number
- the operating system you are using
- the exact wording of any messages that appeared on your screen
- a description of what happened and what you were doing when the problem occurred
- a description of how you tried to solve the problem

Get Web support

In addition to phone support, the Rockwell Automation Customer Support Center offers extensive online knowledgebases of tech notes and frequently asked questions for support of non-urgent issues. These databases are updated daily by our support specialists. Go to http://www.rockwellautomation.com/support/ to sign up for online support.

Once you have signed up for online support you can elect to receive regular e-mail messages with links to the latest tech notes, software updates, and firmware updates for the products that are of interest to you. You can also submit online support requests.

And be sure to check the Arena User Zone section of our Web site at www.ArenaSimulation.com. The User Zone links to a peer-to-peer forum on Arena topics and has a link to a download page where you can check for possible software updates (patches). If you can't find the answer you need, contact your local representative or Arena technical support.

Get training

Do you need training? Rockwell Automation offers a standard training course comprised of lecture and hands-on workshops designed to introduce you to the fundamental concepts of modeling with Arena.

We also offer customized training courses designed to meet your specific needs. These courses can be held in our offices or yours, and we can accommodate one person or twenty. You design the course that's right for you! Simply contact our consulting services group to discuss how we can help you achieve success in your simulation efforts.

Get consulting services

Rockwell Automation provides expert consulting and turnkey implementation of Arena Basic Edition and the entire Arena product suite. Please contact our offices for more information.

Contact us

We strive to help all of our customers become successful in their manufacturing improvement efforts. Toward this objective, we invite you to contact your local representative or Rockwell Automation at any time that we may be of service to you.

<div align="center">

Support E-mail: Arena-Support@ra.rockwell.com
Corporate E-mail: Arena-Info@ra.rockwell.com
Support phone: 1.440.646.3434
URL: www.ArenaSimulation.com
URL: www.RockwellAutomation.com

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2 Getting Started

Introduction

While you may not realize it quite yet, you now have the power to transform your business. Whenever you and others in your organization are wondering "what if…?," you can look into the future to find the answer.

With Arena, you can:

■ **Model** your processes to define, document, and communicate.

■ **Simulate** the future performance of your system to understand complex relationships and identify opportunities for improvement.

■ **Visualize** your operations with dynamic animation graphics.

■ **Analyze** how your system will perform in its "as-is" configuration and under a myriad of possible "to-be" alternatives so that you can confidently choose the best way to run your business.

Our task: Analyze a home mortgage application process

In this chapter, we will examine a simple mortgage application process to illustrate how you can model, simulate, visualize, and analyze with Arena. To begin, we'll look at the process of receiving and reviewing a home mortgage application. We will build the flow-chart shown below, introducing you to the process of modeling and simulating with Arena.
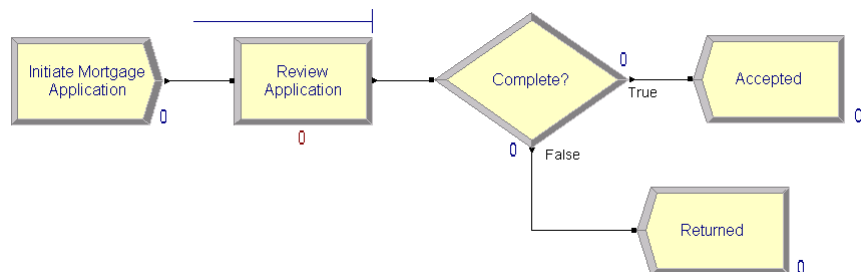
The Arena modeling environment

If Arena is not already running, start it from the Windows Start menu and navigate to **Programs > Rockwell Software > Arena**. The Arena modeling environment will open with a new model window, as shown below.

Project Bar

Model window flowchart view

Model window spreadsheet view
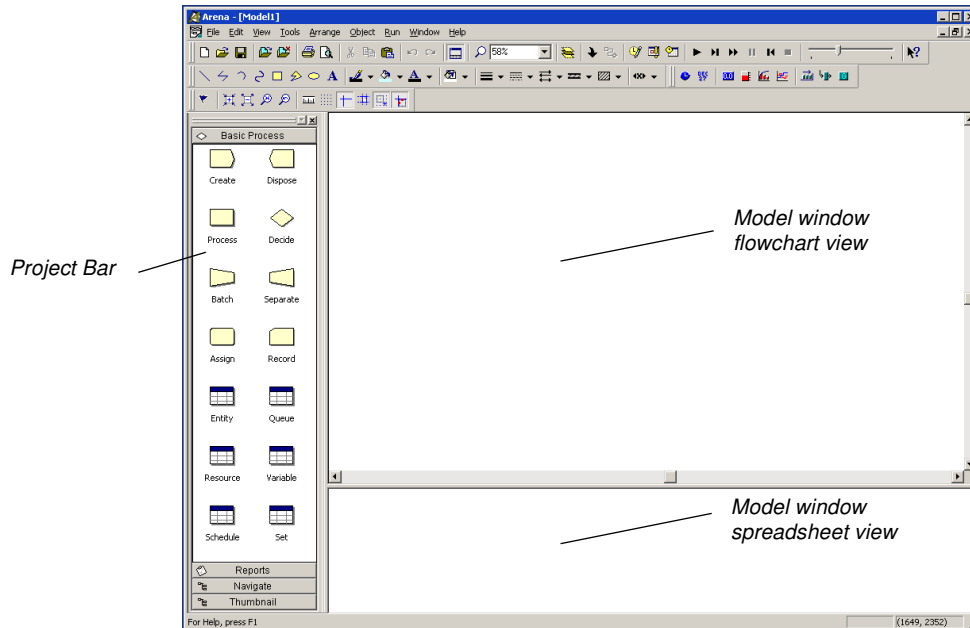
To model your process in Arena, you'll work in three main regions of the application window. The *Project Bar* hosts panels with the primary types of objects that you will work with:

The Project Bar usually is docked at the left of the Arena application window, but can tear off or dock at another position just like any toolbar.

- **Basic Process panel**: Contain the modeling shapes, called *modules*, that you'll use to define your process.

- **Reports panel**: Contains the reports that are available for displaying results of simulation runs.

- **Navigate panel**: Allows you to display different views of your model, including navigating through hierarchical submodels and displaying a model thumbnail.

In the model window, there are two main regions. The *flowchart view* will contain all of your model graphics, including the process flowchart, animation, and other drawing elements. The lower, *spreadsheet view* displays model data, such as times, costs, and other parameters.

As we model the mortgage application process, we'll work in all three of these regions of Arena.

Map your process in a flowchart

Let's start by examining what we're going to do: **Build a flowchart**. The word itself— *flowchart*—suggests two of the main concepts behind modeling and simulation. We'll be building a *chart*—also referred to as a *process map* or a *model*—that describes a *flow*.

This raises a key question in process modeling: **What exactly is it that will *flow* through the chart?**

We're modeling the process of reviewing mortgage applications. These mortgage applica-tions are the items, referred to as *entities,* that will move through the process steps in our model. They are the data, whether on paper or in electronic form, that are associated with our client's request for a mortgage. As we build the flowchart, it's helpful to think of the process from the perspective of the *entity* (the mortgage application), asking questions like:

- Where do the mortgage applications enter the process?
- What happens to them at each step?
- What resources are needed to complete work?

First, we'll draw the flowchart representing the mortgage application process. Refer to the Mortgage Application Process Flowchart (shown previously) so you'll know what we'll be creating.

Create the mortgage application entities

We'll start the flowchart using a *Create module*, from the Basic Process panel. This is the starting point for the flow of entities through the model.

1. Drag the Create module from the Basic Process panel into the model window.

   A default name, Create 1, is given to the module when it's placed. We'll return later to provide a more meaningful description as well as some data to support the simulation.

Every process flow starts with a Create module. When you simulate the flowchart, individual entities will be created according to timing information you supply in the Create module properties. After it's created, each entity moves from the Create module to the next shape in the process flow.
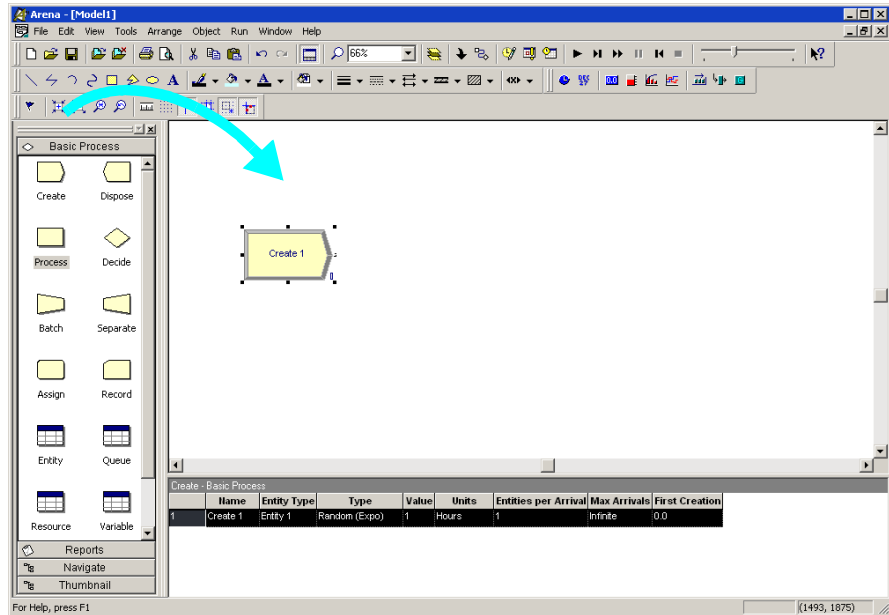
Process the applications

If your Create and Process were not automatically when you placed the Process, check the Object > Auto-Connect menu to verify that it is checked. If it is not, select it to turn on this option.

Next in our flowchart is a *Process module* that represents the Review Application step.

1. Be sure that the Create module is selected so that Arena will automatically connect the Process to the Create module.

2. Drag a Process module from the Basic Process panel into the model window, placing it to the right of the Create. Arena will automatically connect the two modules.

   As with the Create, the Process module has a default name that we'll replace later.
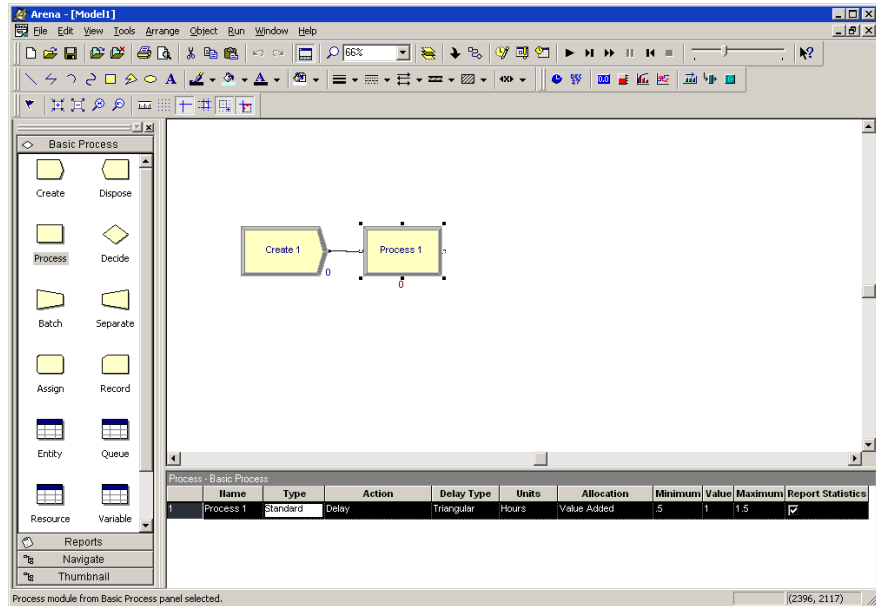
Note: *If no connection appears between Create and Process, click the **Object > Connect** menu item or the **Connect** toolbar button to draw a connection. Your cursor will change to a cross hair. Start the connection by clicking the exit point (►) of the Create module, then click the entry point (■) of the Process module to complete the connection. If you need to make multiple connections, simply double-click the **Connect** button or select **Object > Connect** twice (the Connect button will remain depressed to indicate it is in multi-connect mode). Then draw as many connections as desired. A valid connection target (e.g., entry point, exit point, or operand object) is now highlighted during a connection session if the pointer is hovered over it. To end the multi-connection session, click again on the **Connect** option, press **Esc**, or right-click.*

How do I use Snap and Grid?

If your flowchart shapes aren't lining up properly, you can use Arena's snap and grid features to straighten them out. First, check the **Snap** option on the **View** menu so that newly placed shapes will be positioned at regular snap points. To realign the shapes you've already placed, select the main module shapes (the yellow boxes) by holding the **Ctrl** key and clicking on each shape. Then, click the **Arrange > Snap to Grid** menu option to adjust their positions to align with grid points.

You can display the grid by checking the **Grid** option on the **View** menu. Both snap and grid are turned off by clicking on the menu option again, turning off the check box.

Decide whether applications are complete

After the Process, we have a *Decide module* which determines whether the mortgage application is complete.

1. If you're using the Auto-Connect feature (i.e., it's checked on the **Object > Auto-Connect** menu), be sure that the Process module is selected so that the Decide module will be connected to it.

2. Drag a Decide module to the right of the Process module.
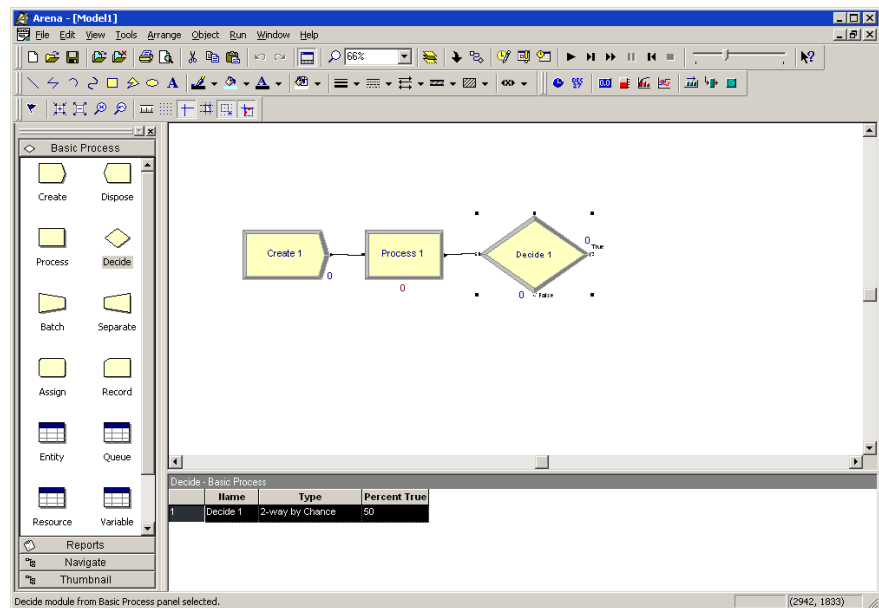
If the mortgage application has a complete set of information, it will leave the Decide module from the right side of the diamond shape, representing the True condition. Incomplete applications (False result to the Decide test) will leave via the bottom connection.

Dispose the applications to terminate the process

Next we'll place the *Dispose module* that represents accepted applications, connecting to the True (right) output from the Decide shape. Then, we'll complete the flowchart with another Dispose for returned applications.

1. Select the Decide shape so that our first Dispose will be connected automatically.

Entity flow always begins with a Create module and terminates with a Dispose module. You may have as many of each of these modules as you need to generate entities into the model and to remove them when their processing is complete.

2. Drag a Dispose module to the right of the Decide module. Arena will connect it to the primary (True) exit point of the Decide module. (We won't include a graphic display since you're now familiar with the drag-and-drop sequence.)

3. To add the second Dispose module, once again select the Decide module, so that Arena will automatically connect its False exit point to the new Dispose module, and drag another Dispose module below and to the right of the Decide module.

4. Drag and drop another Dispose module, placing it below and to the right of the Decide shape, completing the process flowchart.

What is a module?

In Arena, *modules* are the flowchart and data objects that define the process to be simulated. All information required to simulate a process is stored in modules.

For now, we're working with flowchart modules—those that are placed in the model window to describe the process. In the Basic Process panel, these are the first eight shapes:

- **Create:** The start of process flow. Entities enter the simulation here.
- **Dispose:** The end of process flow. Entities are removed from the simulation here.
- **Process:** An activity, usually performed by one or more resources and requiring some time to complete.
- **Decide:** A branch in process flow. Only one branch is taken.
- **Batch:** Collect a number of entities before they can continue processing.
- **Separate:** Duplicate entities for concurrent or parallel processing, or separating a previously established batch of entities.
- **Assign:** Change the value of some parameter (during the simulation), such as the entity's type or a model variable.
- **Record:** Collect a statistic, such as an entity count or cycle time.

Simulation settings are defined in the **Run > Setup > Replication Parameters** dialog box. There is also a set of *data modules* for defining the characteristics of various process elements, such as resources and queues.

Using modules in Arena Basic Edition

Arena Basic Edition includes all of the modules in the Basic Process panel. If you add a module to your model from another template, such as the Advanced Process, Advanced Transfer, Blocks, or Elements panels, Arena will go into demonstration mode.

Define model data

Now that we've drawn the basic flowchart for our mortgage application process, let's define the data associated with the modules, including the name of the module and information that will be used when we simulate the process.

Initiate mortgage application (Create module)
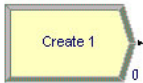
First, let's visit the Create module, which will be named *Initiate Mortgage Application*. Its data will include the type of entity to be created—in our case, a mortgage *Application*. We also need to define how often mortgage applications are initiated. We'll use an average of *2 hours* between applicants as a starting point for our model, and we'll make this a random activity to represent the natural variation in the timing of mortgage applications being submitted.

1. Double-click the Create module to open its property dialog box.

2. In the Name field, type **Initiate Mortgage Application**.

   Name:
   Initiate Mortgage Application

3. For the Entity Type, name our entities by typing **Application**.

   Entity Type:
   Application

4. Type **2** in the Value field of the Time Between Arrivals section.

   Value:
   2

5. Click **OK** to close the dialog box.

For now, we'll leave the default values for the other Create module properties. Feel free to explore their purposes through online help or the *Arrivals* models in the Smarts library.

ℹ️ ## What are entities?

Entities are the items—customers, documents, parts—that are being served, produced, or otherwise acted on by your process. In business processes, they often are documents or electronic records (checks, contracts, applications, purchase orders). In service systems, entities usually are people (the customers being served in a restaurant, hospital, airport, etc.). Manufacturing models typically have some kind of part running through the process, whether it's raw material, a subcomponent, or finished product. Other models might have different types of entities, such as data packets in network analysis or letters and boxes in package-handling facilities.

You may have different types of entities in the same model. For example, customers moving through a check-in counter at an airport might be separated into regular, first-class, and priority entity types. In some cases, entity types might be of an altogether different form rather than classifications of some basic type. For instance, in a pharmacy, prescriptions would be modeled as entities, running through the process of being filled. At the same time, customers might be competing for the pharmacist's attention with medical inquiries; they would also be modeled as entities.

Review application (Process module)

Remember that as we create the flowchart, we're looking at the process from the perspective of the entity. The Create module is a starting point for an entity's flow through the system being modeled. Next, in our case, the application will be reviewed for completeness by a *Mortgage Review Clerk*. Because this will take some amount of time, holding the entity at this point in the flowchart for a *delay* and requiring a *resource* to perform the activity, we use a Process module. We'll call this process *Review Application*.

Appendix A describes the distributions available in Arena.

For the time delay, we also want to capture the natural variability that exists in most processes. Very often, for work done by people or equipment, a triangular distribution provides a good approximation. You specify the *minimum* time in which the work could be done, the *most likely value* for the time delay, and the *maximum* duration of the process.

During the simulation run, each time an entity enters the process, Arena will calculate a sample from the distribution information you've provided—in our case, a triangular distribution. Over the course of a long simulation run where thousands of individual samples are taken, the times will follow the profile illustrated next.
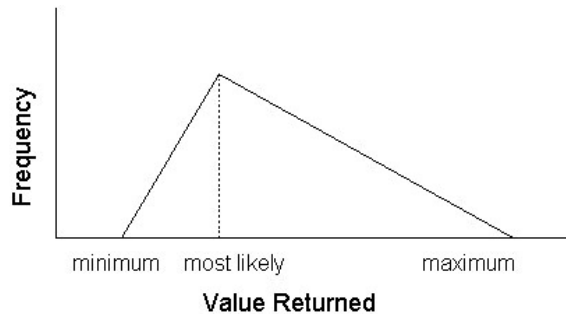
For our Review Application process, we'll use a minimum time of *1 hour*, most likely value of *1.75 hours*, and a maximum of *3 hours*. We will assign a *resource*, the *Mortgage Review Clerk*, to perform this process.

1. Double-click the Process module to open its property dialog box.

If more than one resource is required for a process to be performed, add as many as are necessary in the Process dialog's Resources list. An entity won't commence its process delay until all listed resources are available.

2. In the Name field, type **Review Application**.

Name:

Review Application

3. To define a resource to perform this process, pull down the **Action** list and select **Seize Delay Release**.

Action:

Seize Delay Release

Arriving entities will wait their turn for the resource to be available. When its turn comes, the entity will *seize* the resource, *delay* for the process time, and then *release* the resource to do other work.

4. A list of resources will appear in the center of the dialog box. To add a resource for this process, click **Add**.

5. In the Resource Name field of the Resource dialog box, type **Mortgage Review Clerk**.

> Resource Name:
>
> [Mortgage Review Clerk ▼]

6. Click **OK** to close the Resource dialog box.

7. Define the process delay parameters in the Minimum, Value (Most Likely), and Maximum fields as **1**, **1.75**, and **3**. (Note that the default delay type is Triangular and the default time units are in hours.)

> | Minimum: | Value (Most Likely): | Maximum: |
> | --- | --- | --- |
> | 1 | 1.75 | 3 |

8. Click **OK** to close the dialog box.

For now, we'll leave the default values for the other Process module properties. Feel free to explore their purposes through online help or the *Basic Concepts* and *Resources* models in the Smarts library.

Complete? (Decide module)

After the mortgage application has been reviewed, we determine whether to accept or return the application. In Arena, whenever an entity selects among branches in the process logic, taking just one of the alternatives, a Decide module is used.
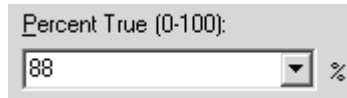
For the mortgage application process, we'll use a simple probability to determine the outcome of the decision, with 88% of applications accepted as complete.

When you use a 2-way Decide module, the entity that enters the module leaves via one of the two exit points. If you want to make copies of an entity to model parallel processes, use a Separate module.

1. Double-click the Decide module to open its property dialog box.

2. In the Name field, type **Complete?**.

> Name:
>
> [Complete? ▼]

15

3. For the Percent True field, type **88** to define the percent of entities that will be treated with a "True" decision (i.e., will depart through the exit point at the right of the Decide module).

Percent True (0-100):

88   %
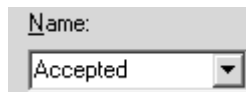
4. Click **OK** to close the dialog box.

Accepted, Returned (Dispose module)
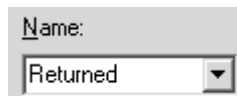
In our simple process for reviewing mortgage applications, all the work that we're interested in is done. Now, we'll remove the mortgage applications from the model, terminating the process with a Dispose module. Because there are two possible outcomes of the mortgage application process—applications can be accepted or returned—we're using two Dispose modules that will count the number of applications under each outcome.

1. Double-click the first Dispose module (connected to the True condition branch of the Decide module) to open its property dialog box, and in the Name field, type **Accepted**.

Name:

Accepted

2. Click **OK** to close the dialog box.

3. Double-click the other Dispose module to open its property dialog box. In the Name field, type **Returned**.

Name:

Returned

4. Click **OK** to close the dialog box.
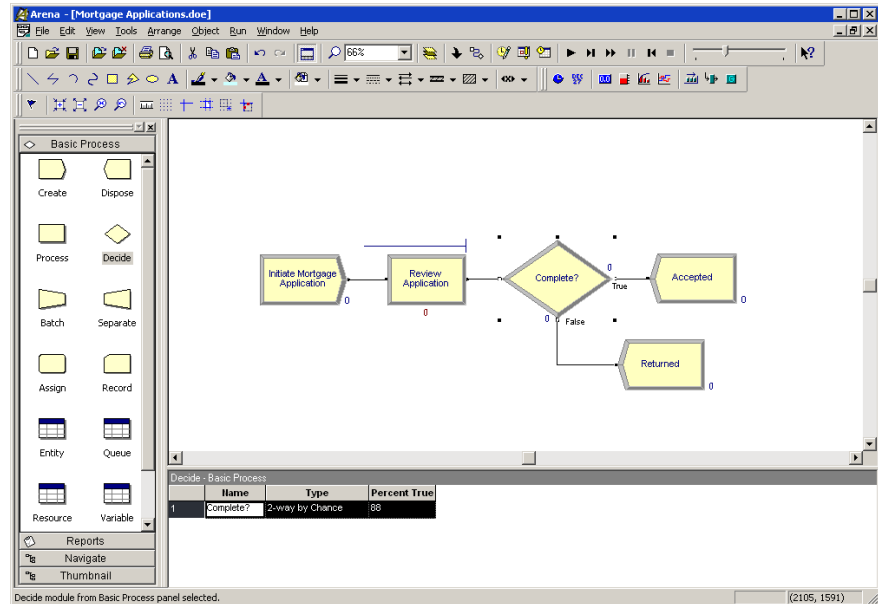
Mortgage review clerk (Resource module)

Along with our flowchart, we also can define parameters associated with other elements of our model, such as resources, entities, queues, etc. For the mortgage process, we'll simply define the cost rate for the Mortgage Review Clerk so that our simulation results will report the cost associated with performing this process. The clerk's costs are fixed at $12 per hour.

To provide these parameters to the Arena model, you'll enter them in the Resources spreadsheet.

You can edit the fields for any module using Arena's spreadsheet, including flowchart modules. Just click on the icon in the Basic Process panel to display its spreadsheet.

1. In the Basic Process panel, click the Resource icon to display the Resources spreadsheet.

2. Because we defined the Mortgage Review Clerk as the resource in the Review Application process, Arena has automatically added a resource with this name in the Resources spreadsheet. Click in the Busy/Hour cell and define the cost rate when the clerk is busy by typing **12**. Click in the Idle/Hour cell and assign the idle cost rate by typing **12**.

	Name	Type	Capacity	Busy / Hour	Idle / Hour	Per Use	StateSet Name	Failures	Report Statistics
1	Mortgage Review Clerk	Fixed Capacity	1	12	12	0.0		0 rows	☑

Double-click here to add a new row.

Prepare for the simulation

To make the model ready for simulation, we'll specify general project information and the duration of the simulation run. Since we're just testing our first-cut model, we'll perform a short, 20-day run.

1. Open the Project Parameters dialog box by using the **Run > Setup** menu item and clicking the **Project Parameters** tab. In the Project Title field, type **Mortgage Review Analysis**; we'll leave the Statistics Collection check boxes as the defaults, with Entities, Queues, Resources, and Processes checked and we'll also check the costing box.

2. Next, click the **Replication Parameters** tab within the same Run Setup dialog box. In the Replication Length field, type **20**; and in the Time Units field directly to the right of Replication Length, select **days** from the drop-down list. Click **OK** to close the dialog box.

Save the simulation model

Now that you've done some work on your model, it seems like a good time to save it. Click **Save** on the Standard toolbar or select the **File > Save** menu item. Arena will prompt you for a destination folder and file name. Browse to the target folder in which you want to save the model (e.g., C:\My Documents) and type a name (e.g., **Mortgage Review**) in the file name field.

Arena's model files store all of the model definition, including the flowchart, other graphics you've drawn, and the module data you entered. When you perform a simulation run, the results are stored in a database using the same name as the model file.

Simulate the process

With these few, short steps, we are ready to predict the future! The mortgage application model contains all of the information needed to run the simulation.

Start the simulation run by clicking the **Go** button or clicking the **Run > Go** menu item. Arena first will check to determine whether you've defined a valid model, then will launch the simulation.

As the simulation progresses, you'll see small entity pictures resembling pages moving among the flowchart shapes. Also, a variety of variables change values as entities are created and processed, as illustrated below.

*If Arena displays an error message, you can use the **Find** button in the error window to locate the source of the problem. You can change between the error and model windows by selecting them from the Window menu.*

Create: Number of entities created

Decide: Number of entities out each branch

Process: Number of entities currently in process

Dispose: Number of entities disposed

If the animation is moving too fast, you can slow it down by adjusting the animation scale factor. For this, you have the following choices:

The animation scale factor is the amount of simulated time between successive screen updates. Smaller values provide smoother, slower animation.

- Open the Run Setup dialog box via the **Run > Speed > Animation Speed Factor** menu item and enter a smaller value (e.g., `0.005`) for the scale factor; *or*

- Use the less-than (**<**) key during the run to decrease the scale factor by 20%. Be sure that the model window is active—not the Navigate panel—or **>** and **<** won't take effect. Pressing **<** repeatedly is an easy way to fine tune the animation speed. The greater-than (**>**) key speeds up animation by 20%.

- Use the slider bar in the main toolbar. Move the slider to the left to slow down the animation; move the slider to the right to speed up the animation.

*If the run finishes before you have a chance to explore these controls, answer No when you're asked if you want to view the results. Then click **Start Over** on the **Run** toolbar to begin the run again.*

To pause the simulation, click the **Pause** button or press the **Esc** key. With the automatic flowchart animation, you can see how many entities have been created, are currently in the Review Application process, have left each branch of our Decide module, and have left the model at each of our terminating Dispose modules. These variables can be helpful in verifying the model. For example, if the probability in the Decide shape was entered incorrectly (e.g., if you typed 12—the rejection probability—instead of 88), the variables would show that many more applications were leaving the Returned branch.

You also can step through the simulation one event at a time. **Pause** the simulation, then click the **Step** button or press the **F10** key. Each time you step the simulation, an entity is moved through the flowchart. Usually, you'll see animation of the entity's movement, though sometimes no visual change will take place (e.g., when the next event is creating a new entity). When this occurs, just step again to move forward to the next event.

View simulation reports

After you've watched some of the animated flowchart, you can quickly run to the end of the simulation to view reports. **Pause** the simulation, then click the **Fast Forward** button to run the simulation without updating the animation.

At the end of the run, Arena will ask whether you'd like to view reports. Click **Yes**, and the default report (the Category Overview Report) will be displayed in a report window, as shown below.

Each of Arena's reports is displayed in its own window within the Arena application. You can use the standard window options (maximize, minimize, etc.) by clicking on the window control buttons or by pulling down the window menu.
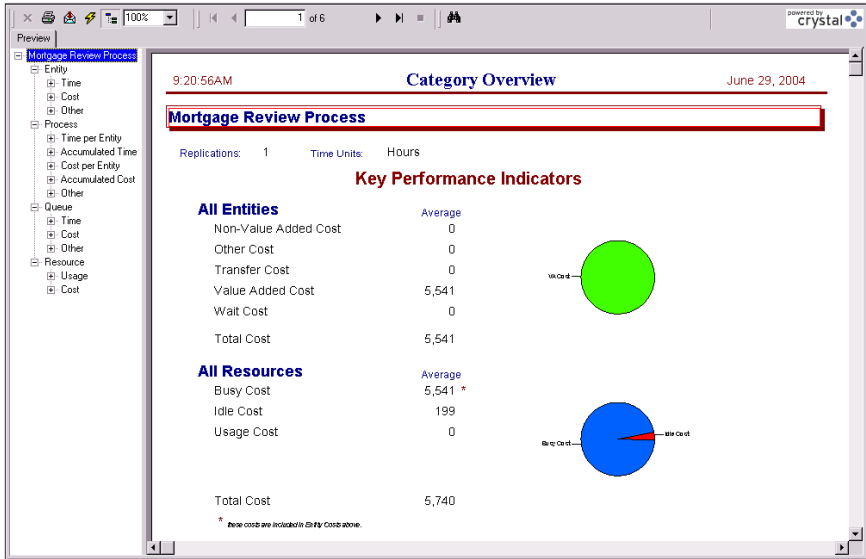
On the left side of each report window is a tree listing the types of information available in the report. The project name (in our case, Mortgage Review) is listed at the top of the tree, followed by an entry for each category of data. This report summarizes the results across all replications (although, in this model, we have only one replication). Other reports provide detail for each replication.

By clicking on the entries inside the category sections, you can view various types of results from the simulation run. The following table illustrates some of the questions you could answer from the Category Overview Report on our simple mortgage application process simulation.

Question	Report Section	Answer
On average, how long did mortgage applications spend in the modeled process?	Total Time (Entity), Average column	16.51 hrs
What was the average cost of reviewing a mortgage application?	Total Cost (Entity), Average column	$22.99
What was the longest time an application spent in review?	Total Time (Process), Maximum column	33.45 hrs
What was the maximum number of applications waiting for review?	Number Waiting (Queue), Maximum column	21 applications
What proportion of time was the Mortgage Review Clerk busy?	Utilization (Resource), Average column	97%

After you've browsed the Category Overview Report, you can close it by clicking on the window icon to the left of the **File** menu and clicking **Close**. You can look at other reports by clicking on their icons in the Project Bar. Each report will be displayed in its own window. To return to the model window, close all of the report windows or select the model file from the Window menu.

After you have viewed the reports and returned to the model window, end the Arena run session by clicking the **End** button.

Enhance the visualization process

Now that we've completed the basic steps for analyzing the mortgage application process, we can return to our model and embellish the graphical animation to gain further insight into the process dynamics. Animation also can be of great benefit in enticing others in the organization to be interested in process improvement.

We'll add two animation components to the mortgage model. First, we'll show our Mortgage Review Clerk working at a desk, either busy or idle. To gain a better sense of how many applications are waiting in the Review Application process over time, we'll also add a dynamic plot of the work-in-process (WIP) simulation variable. Our Arena model will appear as shown below after we add these two objects.

*Note: You can toggle between the split view (flowchart and spreadsheet) and a full-screen view of either area by clicking the **Split Screen** toolbar button or selecting the **View > Split Screen** menu item. When in full-screen view, clicking the icons on the Basic Process panel displays the appropriate view (flowchart for flowchart modules and spreadsheet for data-only modules).*
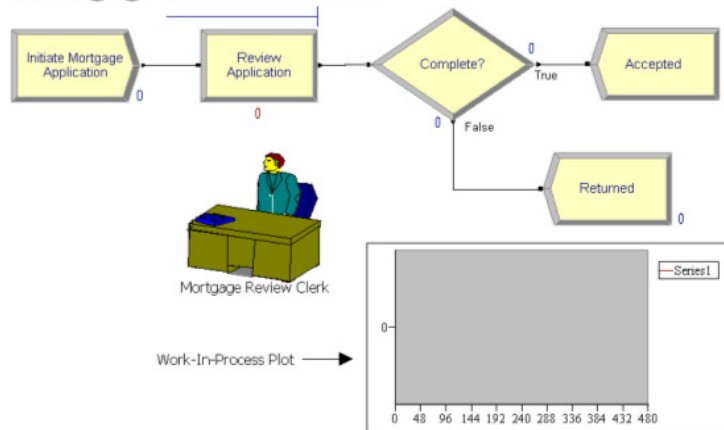
Animate the mortgage review clerk resource

During the simulation run, our Mortgage Review Clerk resource can be in one of two states. If no mortgage application entity is in-process, then the resource is *idle*. We'll use a picture of a person sitting at a desk to depict idleness. When an entity seizes the resource, the Mortgage Review Clerk's state is changed to *busy*, in which case our picture will show the person reviewing a document.

1. Click the **Resource** button on the **Animate** toolbar.

2. The Resource Placement dialog box appears. Select the **Mortgage Review Clerk** from the drop-down list in the Identifier field so that this object animates the Mortgage Review Clerk.

3. Open the Workers picture library by clicking the **Open** button, then browsing to the *Workers.plb* file in the Arena application folder (e.g., C:\Program Files\Rockwell Software\Arena) and double-clicking on it.

4. To change the idle picture:

   ◘ Click the **Idle** button in the table on the left.

   ◘ Select from the picture library table on the right the picture of the worker sitting down.

   ◘ Click the **Transfer** button between the tables to use the worker picture for the Idle resource state.

5. To change the busy picture:

   ◘ Click the **Busy** button in the table on the left.

   ◘ Select from the picture library table on the right the picture of the worker reading a document.

   ◘ Click the **Transfer** button between the tables to use the selected picture when the Mortgage Review Clerk is busy.

6. Click **OK** to close the dialog box. (All other fields can be left with their default values.)

7. The cursor will appear as a cross hair. Move it to the model window and click to place the Mortgage Review Clerk resource animation picture.

8. If you'd like to have the clerk appear a bit larger, select the picture and use the resize handles to enlarge it.

How do I use Rulers and Guides?
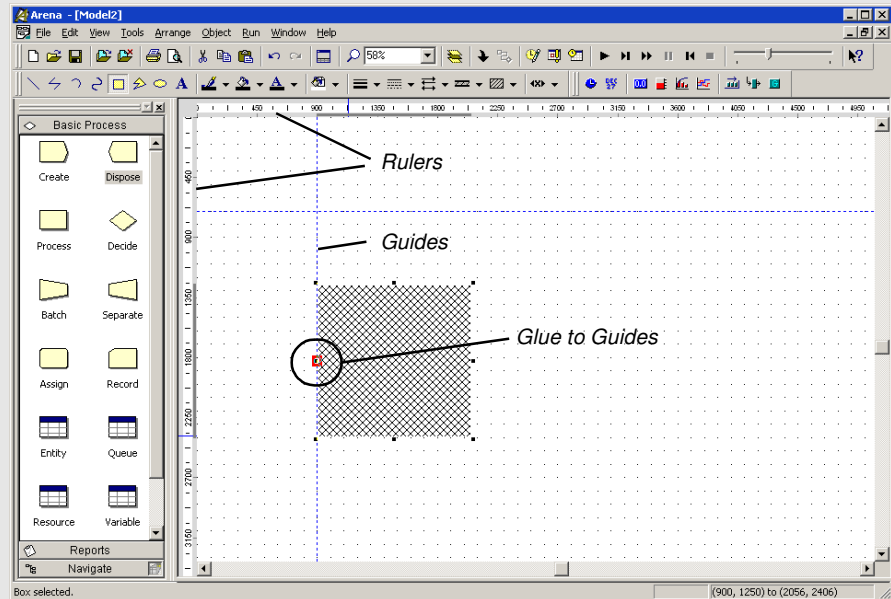
Selecting the **Rulers** command on the **View** menu toggles horizontal and vertical rulers at the top and left edges of each drawing window. The ruler labels display the (+/-) distance from the origin in Arena world units. The spacing between the ruler labels is based on the snap spacing, with the labels rounded to the nearest snap point if **Snap to Grid** is enabled.

When the **Guides** command (**View** menu) is activated, you may add guides into the application window to aid in positioning shapes precisely. You may either drag them from the horizontal or vertical ruler edges independently or drag them simultaneously from the origin corner. If you select a guide, you may drag it to a new position, or you may remove it by pressing **Delete**.

Activating the **Glue to Guides** command **(View** menu) allows you to drag a shape (module or drawing object) to a guide until the shape selection handle turns red (as shown in the circled call-out of the example), which indicates that the shape is "glued" to the guide. The guide may then be dragged to a new location and all shapes glued to the guide will maintain their alignment and will move with the guide.

Plot the number of applications in-process

Our second animation enhancement is a plot of how many mortgage applications are under review as the simulation progresses. This will give us a sense of the dynamics of the workload, which can vary quite a bit when the random nature of processes is incorporated into a simulated model.

1. Click the **Plot** button on the **Animate** toolbar.

2. The Plot dialog box appears. We'll plot a single expression, the work-in-process (WIP) at the Review Application process. To add a data series to a plot, go to the **Data Series** tab page and then click the **Add** button.

You can plot many expressions on the same set of axes by adding multiple expressions in the Plot dialog. Each can be color-coded so that you can readily compare data such as workloads in processes, waiting customers, etc.

3. In the properties grid for the data series (by default it will be named 'Series1'), go to the *Source Data\Expression* property. This property defines the simulation expression to monitor and plot. Type in the expression 'Review Application.WIP'.

4. Now go to the **Axes** tab page and select the Left (Y) Value axis. Change the scale-related properties for that axis to be as listed below (leaving the default for any property not specifically mentioned).

   Specify the value '5' for the *Scale\MajorIncrement* property, so that major tick marks on the y-axis are displayed over 5 units.

5. Now select the horizontal Time (X) axis. Change the scale-related properties for that axis to be as listed below (leaving the default for any property not specifically mentioned).

   Specify the value '480' for the *Scale\Maximum* property. This sets the horizontal time axis of the plot to be 480 hours of simulated time, matching our run length.
   Specify the value '48' for the *Scale\MajorIncrement* property, so that the major tick marks on the x-axis are displayed every 48 hours (or 2 days).

6. Click **OK** to close the Plot dialog.

7. The cursor changes to a cross hair. Draw the plot in the model window by clicking to locate each of the two opposite corners (e.g., the top-left and bottom-right corners), placing the plot below the flowchart and to the right of the resource.

With the edits complete, you may want to save them by clicking **Save** or pressing **Ctrl+S**.

What is a model thumbnail?

The Navigate panel on the Project Bar provides a model navigation tree for maneuvering through the different named views and hierarchical levels defined in the model. Included as part of the Navigate panel is a model thumbnail that helps users orient and change the current view within the active drawing window.

The thumbnail displays the world space of the current drawing window. A colored, translucent rectangle represents the current view's boundaries. Dragging the rectangle in the thumbnail moves the drawing window's current view left, right, up, or down; however, the rectangle may not be dragged outside the boundaries of the world space.

You may also re-center the rectangle, and thus the world space, or change the level of zoom. For details on model thumbnail, see the Navigate Panel topic in online help.

Rerun the simulation

Now that we've made our animation more interesting and valuable, let's run the simulation again. Because we didn't change any of the process parameters (i.e., data in the modules), the simulation will provide the same results.

Click **Run** (or press the **F5** key) to start the simulation. As the simulation progresses, you'll notice the Mortgage Review Clerk's picture change from idle (sitting at the desk) to busy (reading a document) and back again, as mortgage application entities move through the Review Application process.

The plot shows some significant peaks in the number of applications that are under review, caused by the combination of the variation in the time between arrivals of applications (defined in the Create module) and the time to process applications (Process module).
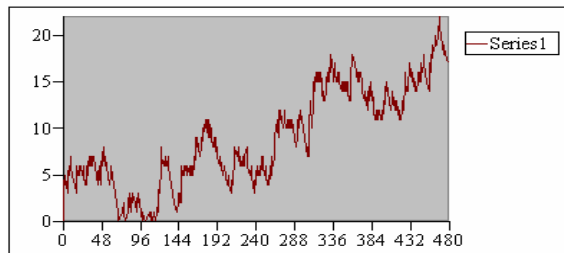
Next steps

You've succeeded in modeling, simulating, visualizing, and analyzing a simple mortgage application process. To further explore Arena's capabilities, try solving a few of these extensions to the process.

1. Add a screening process before the application is reviewed.

   Applications can be screened in as little as 15 minutes. Most often, it takes about 25 minutes for the screening, though sometimes it can require as much as 45 minutes. Assign a Receptionist (rate of $6.75/hour) to perform the screening. What proportion of the Receptionist's time will be used in this task?

2. Return some applications to the mortgage applicants after the screening process.

   On completion of the screening, 8% of the applications are returned. Also, because many of the deficient applications are caught in the new screening, the percentage of applications that are accepted in the formal review is raised from 88% to 94%, and the Mortgage Review process time is reduced by 10%. By how much did the cost of reviewing an application change? How about the total time to review applications?

To view completed Arena models for the main tutorial and these two extensions, browse to the Examples folder and open *Mortgage Applications.doe*, *Mortgage Extension 1.doe*, and *Mortgage Extension 2.doe*.

3 The Basic Process Panel

This chapter describes the flowchart and data modules that you'll use to model your process. Additionally, this chapter includes example uses of each module.

Flowchart modules

Flowchart modules are the set of objects that are placed in the model window to describe the simulation process.

Create module

DESCRIPTION

Number of entities created

This module is intended as the starting point for entities in a simulation model. Entities are created using a schedule or based on a time between arrivals. Entities then leave the module to begin processing through the system. The entity type is specified in this module.
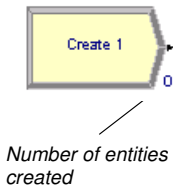
TYPICAL USES

- The start of a part's production in a manufacturing line
- A document's arrival (e.g., order, check, application) into a business process
- A customer's arrival at a service process (e.g., retail store, restaurant, information desk)

PROMPTS

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Entity Type	Name of the entity type to be generated.
Type	Type of arrival stream to be generated. Types include **Random** (uses an exponential distribution, user specifies mean), **Schedule** (uses an exponential distribution, mean determined from the specified Schedule module), **Constant** (user specifies constant value; e.g., 100), or **Expression** (drop-down list of various distributions).
Value	Determines the mean of the exponential distribution (if *Random* is used) or the constant value (if *Constant* is used) for the time between arrivals. Applies only when Type is Random or Constant.
Schedule Name	Identifies the name of the schedule to be used. The schedule defines the arrival pattern for entities arriving to the system. Applies only when Type is Schedule.

Prompt	Description
Expression	Any distribution or value specifying the time between arrivals. Applies only when Type is Expression.
Units	Time units used for interarrival and first creation times. Does not apply when Type is Schedule.
Entities per Arrival	Number of entities that will enter the system at a given time with each arrival.
Max Arrivals	Maximum number of arrivals that this module will generate. When this value is reached, the creation of new arrivals by this module ceases.
First Creation	Starting time for the first entity to arrive into the system. Does not apply when Type is Schedule.

Dispose module

DESCRIPTION

Number of entities that have been disposed

This module is intended as the ending point for entities in a simulation model. Entity statistics may be recorded before the entity is disposed.

TYPICAL USES

■ Parts leaving the modeled facility
■ The termination of a business process
■ Customers departing the store

PROMPTS

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Record Entity Statistics	Determines whether or not the incoming entity's statistics will be recorded. Statistics include value-added time, non-value-added time, wait time, transfer time, other time, total time, value-added cost, non-value-added cost, wait cost, transfer cost, other cost, and total cost.
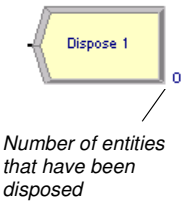
Process module

DESCRIPTION

Indicator of a submodel process

This module is intended as the main processing method in the simulation. Options for seizing and releasing resource constraints are available. Additionally, there is the option to use a "submodel" and specify hierarchical user-defined logic. The process time is allocated to the entity and may be considered to be value added, non-value added, transfer, wait, or other. The associated cost will be added to the appropriate category.

TYPICAL USES

- Machining a part
- Reviewing a document for completeness
- Fulfilling orders
- Serving a customer

Number of entities currently in process

PROMPTS

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Type	Method of specifying logic within the module. **Standard** processing signifies that all logic will be stored within the Process module and defined by a particular Action. **Submodel** indicates that the logic will be hierarchically defined in a "submodel" that can include any number of logic modules.
Action	Type of processing that will occur within the module. **Delay** simply indicates that a process delay will be incurred with no resource constraints. **Seize Delay** indicates that a resource(s) will be allocated in this module and delay will occur, but that resource release will occur at a later time. **Seize Delay Release** indicates that a resource(s) will be allocated followed by a process delay and then the allocated resource(s) will be released. **Delay Release** indicates that a resource(s) has previously been allocated and that the entity will simply delay and release the specified resource(s). Applies only when Type is Standard.
Priority	Priority value of the entity waiting at this module for the resource(s) specified if one or more entities are waiting for the same resource(s) anywhere in the model. Not visible when Action is Delay or Delay Release or when Type is Submodel.
Resources	Lists the resources or resource sets used for entity processing. Does not apply when Action is Delay, or when Type is Submodel.

Prompt	Description
Delay Type	Type of distribution or method of specifying the delay parameters. **Constant** and **Expression** require single values, while **Normal**, **Uniform**, and **Triangular** require several parameters.
Units	Time units for delay parameters.
Allocation	Determines how the processing time and process costs will be allocated to the entity. The process may be considered to be **Value Added**, **Non-Value Added**, **Transfer**, **Wait**, or **Other** and the associated cost will be added to the appropriate category for the entity and process.
Minimum	Parameter field for specifying the minimum value for either a uniform or triangular distribution.
Value	Parameter field for specifying the **mean** for a normal distribution, the **value** for a constant time delay, or the **mode** for a triangular distribution.
Maximum	Parameter field for specifying the maximum value for either a uniform or triangular distribution.
Std Dev	Parameter field for specifying the standard deviation for a normal distribution.
Expression	Parameter field for specifying an expression whose value is evaluated and used for the processing time delay.
Report Statistics	Specifies whether or not statistics will be automatically collected and stored in the report database for this process.

Process module — Resource dialog

PROMPTS

Prompt	Description
Type	Specification of a particular resource, or selecting from a pool of resources (i.e., a resource set).
Resource Name	Name of the resource that will be seized and/or released. Applies only when Type is Resource.
Set Name	Name of the resource set from which a member will be seized and/or released. Applies only when Type is Set
Quantity	Number of resources of a given name or from a given set that will be seized/released. For sets, this value specifies only the number of a selected resource that will be seized/released (based on the resource's capacity), not the number of members of a set to be seized/released.
Selection Rule	Method of selecting among available resources in a set. Cyclical will cycle through available members (e.g., 1st member–2nd member–3rd member–1st member–2nd member–3rd member). **Random** will randomly select a member. **Preferred Order** will always select the first available member (1st member, if available; then 2nd member, if available; then 3rd member, etc.). **Specific Member** requires an input attribute value to specify which member of the set (previously saved in the Save Attribute field). **Largest Remaining Capacity** and **Smallest Number Busy** are used for resources with multiple capacity. Applies only when Type is Set.
Save Attribute	Attribute name used to save the index number into the set of the member that is selected. This attribute can later be referenced with the Specific Member selection rule. Does not apply when Selection Rule is Specific Member. If Action is specified as Delay Release, the value specified defines which member (the index number) of the set to be released. If no attribute is specified, the entity will release the member of the set that was *last* seized.
Set Index	The index number into the set of the member requested. Applies only when Selection Rule is Specific Member. If Action is specified as Delay Release, the value specified defines which member (the index number) of the set is to be released.

Decide module

DESCRIPTION

Number of entities that have taken the True branch

This module allows for decision-making processes in the system. It includes options to make decisions based on one or more conditions (e.g., if entity type is Gold Card) or based on one or more probabilities (e.g., 75%, true; 25%, false). Conditions can be based on attribute values (e.g., Priority), variable values (e.g., Number Denied), the entity type, or an expression (e.g., NQ(ProcessA.Queue)).

There are two exit points out of the Decide module when its specified type is either 2-way Chance or 2-way Condition. There is one exit point for "true" entities and one for "false" entities. When the N-way Chance or Condition type is specified, multiple exit points are shown for each condition or probability and a single "else" exit. The number of entities that exit from each type (true/false) is displayed for 2-way Chance or Condition modules only.

Number of entities that have taken the False branch

TYPICAL USES

- Dispatching a faulty part for rework
- Branching accepted vs. rejected checks
- Sending priority customers to a dedicated process

PROMPTS

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Type	Indicates whether the decision is based on a condition (if X>Y) or by chance/percentage (e.g., 60%, yes; 40%, no). The type can be specified as either 2-way or N-way. 2-way allows for one condition or probability (plus the "false" exit). N-way allows for any number of conditions or probabilities to be specified as well as an "else" exit.
Conditions	Defines one or more conditions used to direct entities to different modules. Applies only when Type is N-way by Condition.
Percentages	Defines one or more percentages used to direct entities to different modules. Applies only when Type is N-way by Chance.
Percent True	Value that will be checked to determine the percentage of entities sent out a given True exit.
If	Types of conditions that are available for evaluation: Variable, Variable Array (1D), Variable Array (2D), Attribute, Entity Type, Expression.
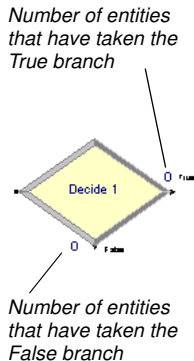
Prompt	Description
Named	Specifies either the name of the variable, attribute, or entity type that will be evaluated when an entity enters the module. Does not apply when Type is Expression.
Is	Evaluator for the condition. Applies only to Attribute and Variable conditions.
Row	Specifies the row index for a variable array. Applies only when Type is N-way by Condition or 2-way by Condition and Variable is Array 1-D or Array 2-D.
Column	Specifies the column index for a variable array. Applies only when Type is N-way by Condition or 2-way by Condition and Variable is Array 1-D or Array 2-D.
Value	Expression that will be either compared to an attribute or variable or that will be evaluated as a single expression to determine if it is true or false. Does not apply to Entity Type condition. If Type is Expression, this value must also include the evaluator (e.g., Color<>Red).

Batch module

DESCRIPTION

Number of entities waiting to be batched

This module is intended as the grouping mechanism within the simulation model. Batches can be permanently or temporarily grouped. Temporary batches must later be split using the Separate module.

Batches may be made with any specified number of entering entities or may be matched together based on an attribute. Entities arriving at the Batch module are placed in a queue until the required number of entities has accumulated. Once accumulated, a new representative entity is created.

TYPICAL USES

- Collect a number of parts before starting processing
- Reassemble previously separated copies of a form
- Bring together a patient and his record before commencing an appointment

PROMPTS

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Type	Method of batching entities together.
Batch Size	Number of entities to be batched.
Save Criterion	Method for assigning representative entity's user-defined attribute values.
Rule	Determines how incoming entities will be batched. **Any Entity** will take the first "Batch Size" number of entities and put them together. **By Attribute** signifies that the values of the specified attribute must match for entities to be grouped. For example, if Attribute Name is Color, all entities must have the same Color value to be grouped; otherwise, they will wait at the module for additional incoming entities.
Attribute Name	Name of the attribute whose value must match the value of the other incoming entities in order for a group to be made. Applies only when Rule is By Attribute.
Representative Entity	The entity type for the representative entity.

Separate module

DESCRIPTION

The original leaves on this branch
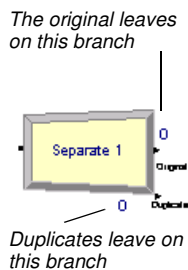

Duplicates leave on this branch

This module can be used to either copy an incoming entity into multiple entities or to split a previously batched entity. Rules for allocating costs and times to the duplicate are also specified. Rules for attribute assignment to member entities are specified as well.

When splitting existing batches, the temporary representative entity that was formed is disposed and the original entities that formed the group are recovered. The entities proceed sequentially from the module in the same order in which they originally were added to the batch.

When duplicating entities, the specified number of copies is made and sent from the module. The original incoming entity also leaves the module.

TYPICAL USES

■ Send individual entities to represent boxes removed from a container
■ Send an order both to fulfillment and billing for parallel processing
■ Separate a previously batched set of documents

PROMPTS

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Type	Method of separating the incoming entity. **Duplicate Original** will simply take the original entity and make some number of identical duplicates. **Split Existing Batch** requires that the incoming entity be a temporarily batched entity using the Batch module. The original entities from the batch will be split.
Percent Cost to Duplicates	Allocation of costs and times of the incoming entity to the outgoing duplicates. This value is specified as a percentage of the original entity's costs and times (between 0-100). The percentage specified will be split evenly between the duplicates, while the original entity will retain any remaining cost/time percentage. Visible only when Type is Duplicate Original.
# of Duplicates	Number of outgoing entities that will leave the module, in addition to the original incoming entity. Applies only when Type is Duplicate Original.
Member Attributes	Method of determining how to assign the representative entity attribute values to the original entities.These options relate to six of the special-purpose attributes (Entity.Type, Entity.Picture, Entity.Sequence, Entity.Station, Entity.Jobstep, and Entity.HoldCostRate) and all user-defined attributes. Applies only when Type is Split Existing Batch.
Attribute Name	Name of representative entity attribute(s) that are assigned to original entities of the group. Applies only when Member Attributes is Take Specific Representative Values.

Assign module

DESCRIPTION

Assign 1

This module is used for assigning new values to variables, entity attributes, entity types, entity pictures, or other system variables. Multiple assignments can be made with a single Assign module.

TYPICAL USES

- Accumulate the number of subassemblies added to a part
- Change an entity's type to represent the customer copy of a multi-page form
- Establish a customer's priority

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Assignments	Specifies the one or more assignments that will be made when an entity executes the module.
Type	Type of assignment to be made. Other can include system variables, such as resource capacity or simulation end time.
Variable Name	Name of the variable that will be assigned a new value when an entity enters the module. Applies only when Type is Variable, Variable Array (1D), or Variable Array (2D).
Row	Specifies the row index for a variable array.
Column	Specifies the column index for a variable array.
Attribute Name	Name of the entity attribute that will be assigned a new value when the entity enters the module. Applies only when Type is Attribute.
Entity Type	New entity type that will be assigned to the entity when the entity enters the module. Applies only when Type is Entity Type.
Entity Picture	New entity picture that will be assigned to the entity when the entity enters the module. Applies only when Type is Entity Picture.
Other	Identifies the special system variable that will be assigned a new value when an entity enters the module. Applies only when Type is Other.
New Value	Assignment value of the attribute, variable, or other system variable. Does not apply when Type is Entity Type or Entity Picture.

Record module

DESCRIPTION

This module is used to collect statistics in the simulation model. Various types of observational statistics are available, including time between exits through the module, entity statistics (time, costing, etc.), general observations, and interval statistics (from some time stamp to the current simulation time). A count type of statistic is available as well. Tally and Counter sets can also be specified.

TYPICAL USES

- Collect the number of jobs completed each hour
- Count how many orders have been late being fulfilled
- Record the time spent by priority customers in the main check-out line

PROMPTS

Prompt	Description
Name	Unique module identifier displayed on the module shape.
Type	Type of observational (tally) or count statistic to be generated. **Count** will increase or decrease the value of the named statistic by the specified value. **Entity Statistics** will generate general entity statistics, such as time and costing/duration information. **Time Interval** will calculate and record the difference between a specified attribute's value and current simulation time. **Time Between** will track and record the time between entities entering the module. **Expression** will record the value of the specified expression.
Attribute Name	Name of the attribute whose value will be used for the interval statistics. Applies only when Type is Interval.
Value	Value that will be recorded to the observational statistic when Type is Expression or added to the counter when Type is Count.
Tally Name	This field defines the symbol name of the tally into which the observation is to be recorded. Applies only when Type is Time Interval, Time Between, or Expression.
Counter	This field defines the symbol name of the counter to *Name* increment/ decrement. Applies only when Type is Counter.
Record into Set	Check box to specify whether or not a tally or counter set will be used.
Tally Set Name	Name of the tally set that will be used to record the observational-type statistic. Applies only when Type is Time Interval, Time Between, or Expression.
Counter Set Name	Name of the counter set that will be used to record the count-type statistic. Applies only when Type is Count.
Set Index	Index into the tally or counter set.

Data modules

Data modules are the set of objects in the spreadsheet view of the model that define the characteristics of various process elements, such as resources and queues.

Attribute module

DESCRIPTION

This data module is used to define an attribute's dimension, datatype and initial value(s). An attribute is a characteristic of all entities, but with a specific value that can differ from one entity to another. Attributes can be referenced in other modules (e.g. the Decide module), can be reassigned a new value with the Assign module, and can be used in any expression. Attribute values are unique for each entity, as compared to Variables which are global to the simulation module.

There are three methods for manually editing the Initial Values of an Attribute module:

- Via the standard spreadsheet interface. In the module spreadsheet, right-click on the **Initial Values** cell and select the **Edit via spreadsheet** menu item. The values for two-dimensional arrays should be entered one column at a time. Array elements not explicitly assigned are assumed to have the last entered value.

- Via the module dialog box. In the module spreadsheet, right-click on any cell and select the **Edit via dialog** menu item. The values for two-dimensional arrays should be entered one column at a time. Array elements not explicitly assigned are assumed to have the last entered value.

- Via the two-dimensional (2-D) spreadsheet interface. In the module spreadsheet, click on the **Initial Values** cell.

TYPICAL USES

- due date of an order (entity)
- priority of order (entity)
- color of a part (entity)

PROMPTS

Prompt	Description
Name	The unique name of the attribute being defined.
Rows	Number of rows in a dimensional attribute.
Columns	Number of columns in a dimensional attribute.

Prompt	Description
Data Type	The data type of the values stored in the attribute. Valid types are **Real** and **String**. The default type is **Real**.
Initial Values	Lists the initial value(s) of the attribute. This value(s) may be changed with the Assign module.
Initial Value	Entity attribute value when entity is created and enters the system

Entity module

DESCRIPTION

This data module defines the various entity types and their initial picture values in a simulation. Initial costing information and holding costs are also defined for the entity.

TYPICAL USES

- Items being produced or assembled (parts, pallets)
- Documents (forms, e-mails, faxes, reports)
- People moving through a process (customers, callers)

PROMPTS

Prompt	Description
Entity Type	The name of the entity type being defined. This name must be unique.
Initial Picture	Graphical representation of the entity at the start of the simulation. This value can be changed during the simulation using the Assign module.
Holding Cost/Hour	Hourly cost of processing the entity through the system. This cost is incurred when the entity is anywhere in the system.
Initial VA Cost	Initial cost value that will be assigned to the value-added cost attribute of the entity. This attribute accrues the costs incurred when an entity is spending time in a value-added activity.
Initial NVA Cost	Initial cost value that will be assigned to the non-value-added cost attribute of the entity. This attribute accrues the costs incurred when an entity is spending time in a non-value-added activity.
Initial Waiting Cost	Initial cost value that will be assigned to the waiting-cost attribute of the entity. This attribute accrues the costs incurred when an entity is spending time in a wait activity; e.g., waiting to be batched or waiting for resource(s) at a Process module.

Prompt	Description
Initial Transfer Cost	Initial cost value that will be assigned to the transfer cost attribute of the entity. This attribute accrues the costs incurred when an entity is spending time in a transfer activity.
Initial Other Cost	Initial cost value that will be assigned to the other cost attribute of the entity. This attribute accrues the costs incurred when an entity is spending time in an other activity.
Report Statistics	Specifies whether or not statistics will be collected automatically and stored in the report database for this entity type.

Queue module

DESCRIPTION

This data module may be utilized to change the ranking rule for a specified queue. The default ranking rule for all queues is First In, First Out unless otherwise specified in this module. There is an additional field that allows the queue to be defined as shared. You cannot use shared queues in Arena Basic Edition.

TYPICAL USES

- Stack of work waiting for a resource at a Process module
- Holding area for documents waiting to be collated at a Batch module

PROMPTS

Prompt	Description
Name	The name of the queue whose characteristics are being defined. This name must be unique.
Type	Ranking rule for the queue, which can be based on an attribute. Types include **First In, First Out**; **Last In, First Out**; **Lowest Attribute Value** (first); and **Highest Attribute Value** (first). A low attribute value would be 0 or 1, while a high value may be 200 or 300.
Attribute Name	Attribute that will be evaluated for the Lowest Attribute Value or Highest Attribute Value types. Entities with lowest or highest values of the attribute will be ranked first in the queue, with ties being broken using the First In, First Out rule.

Prompt	Description
Shared	Check box that determines whether a specific queue is used in multiple places within the simulation model. Shared queues can only be used for seizing resources (e.g., with the Seize module from the Advanced Process panel). You cannot use shared queues in Arena Basic Edition.
Report Statistics	Specifies whether or not statistics will be collected automatically and stored in the report database for this queue.

Resource module

DESCRIPTION

This data module defines the resources in the simulation system, including costing information and resource availability. Resources may have a fixed capacity that does not vary over the simulation run or may operate based on a schedule. Resource failures and states can also be specified in this module.

TYPICAL USES

- Equipment (machinery, cash register, phone line)
- People (clerical, order processing, sales clerks, operators)

PROMPTS

Prompt	Description
Name	The name of the resource whose characteristics are being defined. This name must be unique.
Type	Method for determining the capacity for a resource. **Fixed Capacity** will not change during the simulation run. **Based on Schedule** signifies that a Schedule module is used to specify the capacity and duration information for the resource.
Capacity	Number of resource units of a given name that are available to the system for processing. Applies only when Type is Fixed Capacity.
Schedule Name	Identifies the name of the schedule to be used by the resource. The schedule defines the capacity of a resource for a given period of time. Applies only when Type is Schedule.
Schedule Rule	Dictates when the actual capacity change is to occur when a decrease in capacity is required for a busy resource unit. Applies only when Type is Schedule.

Prompt	Description
Busy/Hour	Cost per hour of a resource that is processing an entity. The resource becomes busy when it is originally allocated to an entity and becomes idle when it is released. During the time when it is busy, cost will accumulate based on the busy/hour cost. The busy cost per hour is automatically converted to the appropriate base time unit specified within the Replication Parameters page of the **Run > Setup** menu item.
Idle/Hour	Cost per hour of a resource that is idle. The resource is idle while it is not processing an entity. During the time when it is idle, cost will accumulate based on the idle/hour cost. The idle cost per hour is automatically converted to the appropriate base time unit specified within the Replication Parameters page of the **Run > Setup** menu item.
Per Use	Cost of a resource on a usage basis, regardless of the time for which it is used. Each time the resource is allocated to an entity, it will incur a per-use cost.
StateSet Name	Name of states that the resource may be assigned during the simulation run.
Initial State	Initial state of a resource. If specified, the name must be defined within the repeat group of state names. This field is shown only when a StateSet Name is defined.
Failures	Lists all failures that will be associated with the resource.
	■ *Failure Name*–Name of the failure associated with the resource.
	■ *Failure Rule*–Behavior that should occur when a failure is to occur for a busy resource unit.
Report Statistics	Specifies whether or not statistics will be collected automatically and stored in the report database for this resource.

Variable module

DESCRIPTION

This data module is used to define a variable's dimension and initial value(s). Variables can be referenced in other modules (e.g., the Decide module), can be reassigned a new value with the Assign module, and can be used in any expression.

There are three methods for manually editing the Initial Values of a Variable module:

■ Via the standard spreadsheet interface. In the module spreadsheet, right-click on the **Initial Values** cell and select the **Edit via spreadsheet** menu item. The values

for two-dimensional arrays should be entered one column at a time. Array elements not explicitly assigned are assumed to have the last entered value.

■ Via the module dialog box. In the module spreadsheet, right-click on any cell and select the **Edit via dialog** menu item. The values for two-dimensional arrays should be entered one column at a time. Array elements not explicitly assigned are assumed to have the last entered value.

■ Via the two-dimensional (2-D) spreadsheet interface. In the module spreadsheet, click on the **Initial Values** cell.

TYPICAL USES

■ Number of documents processed per hour
■ Serial number to assign to parts for unique identification
■ Space available in a facility

PROMPTS

Prompt	Description
Name	The unique name of the variable being defined.
Rows	Number of rows in a dimensional variable.
Columns	Number of columns in a dimensional variable.
Data Type	The data type of the values stored in the variable. Valid types are **Real** and **String**. The default type is **Real**.
Statistics	Check box for determining whether or not statistics will be collected. This field is visible when the rows and columns are not specified (single variables).
Clear Option	Defines the time (if at all) when the value(s) of the variable is reset to the initial value(s) specified. Specifying **Statistics** indicates to reset this variable to its initial value(s) whenever statistics are cleared. Specifying **System** indicates to reset this variable to its initial value(s) whenever the system is cleared. **None** indicates to never reset this variable to its initial value(s), except prior to the first replication.
Initial Values	Lists the initial value(s) of the variable. This value(s) may be changed with the Assign module.
Initial Value	Variable value at the start of the simulation.
Report Statistics	Specifies whether or not statistics will be collected automatically and stored in the report database for this variable.

Schedule module

DESCRIPTION

This data module may be used in conjunction with the Resource module to define an operating schedule for a resource or with the Create module to define an arrival schedule. Additionally, a schedule may be used and referenced to factor time delays based on the simulation time.

TYPICAL USES

- Work schedule for staff, including breaks
- Breakdown patterns for equipment
- Volume of customers arriving at a store
- Learning-curve factors for new workers

PROMPTS

Prompt	Description
Name	The name of the schedule being defined. This name must be unique.
Type	Type of schedule being defined. This may be **Capacity** related (for resource schedules), **Arrival** related (for the Create module), or **Other** (miscellaneous time delays or factors).
Time Units	Time units used for the time-duration information.
Scale Factor	Method of scaling the schedule for increases or decreases in Arrival/Other values. The specified Value fields will be multiplied by the scale factor to determine the new values. Not available for Capacity-type schedules.
Durations	Lists the value and duration pairs for the schedule. Values can be capacity, arrival, or other type values, while the duration is specified in time units. Schedule pairs will repeat after all durations have been completed, unless the last duration is left blank (infinite). Schedule data can be entered graphically using the Graphical Schedule editor or manually using the Value/Duration fields.
Value	Represents either the capacity of a resource (if Type is Capacity), arrival rate (if Type is Arrival), or some other value (if Type is Other). Examples of Other may be a factor that is used in a delay expression to scale a delay time during various parts of the day.
Duration	Time duration for which a specified Value will be valid.

Set module

DESCRIPTION

This data module defines various types of sets, including resource, counter, tally, entity type, and entity picture. Resource sets can be used in the Process modules. Counter and Tally sets can be used in the Record module.

TYPICAL USES

- Machines that can perform the same operations in a manufacturing facility
- Supervisors, check-out clerks in a store
- Shipping clerks, receptionists in an office
- Set of pictures corresponding to a set of entity types

PROMPTS

Prompt	Description
Name	The unique name of the set being defined.
Type	Type of set being defined.
Members	Repeat group that specifies the resource members with the set. The order of listing the members within the repeat group is important when using selection rules such as Preferred Order and Cyclical.
Resource Name	Name of the resource to include in the resource set. Applies only when Type is Resource.
Tally Name	Name of the tally within the tally set. Applies only when Type is Tally.
Counter Name	Name of the counter within the counter set. Applies only when Type is Counter.
Entity Type	Name of the entity type within the entity type set. Applies only when Type is Entity.
Picture Name	Name of the picture within the picture set. Applies only when Type is Entity Picture.

4 Using Visio and Arena

Introduction

Since the mid-1980s, Business Process Improvement (BPI) and simulation have become leading methodologies to allow corporations to deliver high-quality products and services through business process modeling. Businesses are seeking not simply to automate existing operations, but to improve and redesign business processes to meet and exceed customers' expectations for the delivery of products and services.

Many simulation systems are standalone, running only on a desktop and having limited capabilities to integrate with other technologies such as company databases, workflow engines, and other desktop solutions. At the same time, leading corporations have discovered the value of simulation technology. Many companies require simulation to be used as standard procedure in support of process improvements.

A much greater return on investment is possible if process descriptions and simulation results can be accessed throughout the enterprise. Microsoft® Visio®, the leading desktop drawing product, supplies a common graphics platform for representing business process models. Visio's open architecture via ActiveX® and Visual Basic® for Applications enables the overall modeling tool to be customized to fit changing needs. The models also can be shared throughout the enterprise by publishing on an intranet directly from Visio.

The Arena Basic Edition includes a built-in interface to Visio, mapping shapes from a Visio drawing to the appropriate simulation constructs in Arena. Process hierarchy is captured in the Arena simulation model, including activity-based costing and process logic, enabling an understanding of the distribution of cost and effort among process components. As with Visio, Arena supplies robust ActiveX support, a Microsoft® Office-compatible interface, and VBA to fulfill enterprise needs for best-of-breed software products.

The Visio Process Simulation add-in

If you use Visio, you can immediately put Arena's process mapping tool to work with the Visio Process Simulator. Created as an add-in to Visio, the Process Simulator includes a Visio template and stencil for mapping processes with shapes designed to mirror the flow-chart and data modules in the Basic Process panel of the Arena Basic Edition. When you've completed your Visio process map using these tools, you're ready to simulate it in Arena!

Start a drawing

Before opening the Visio stencil, it is necessary to have an administrator on the machine set the Visio macro security options to Low so that macros will be enabled.

To begin a drawing, browse to the Process Simulation template, which the Process Simulator installs in the Program Files\Rockwell Software\Arena\Visio folder. This dialog box typically appears when you first start Visio, or you can bring it up via the **File > New > Choose Drawing Type > Browse Templates** menu.

*It's important to start your drawing by browsing to the Process Simulation **template**, rather than opening or starting a new drawing and directly attaching the Process Simulation **stencil**. If you don't start your drawing with the template, custom dialogs and other features may not be available.*

The Process Simulation template sets up the Visio environment to work with Arena and opens a new drawing. Drawings that are started with this template will automatically display the Process Simulation stencil, provide custom dialog boxes for editing shape properties, and add a Simulate menu to Visio for checking your drawing and transferring it to Arena.

The Process Simulation stencil, which is opened with your new drawing, contains shapes that will capture your process flow and data. The shapes mirror those in Arena's Basic Process panel, so you can use Visio to define fully a model of your process, including all of the parameters needed to exploit the power of simulation analysis.

The first 14 shapes in the Process Simulation stencil correspond to the Arena flowchart and data modules with the same names. In addition, the Visio stencil contains five connector shapes for properly defining the process flowchart.
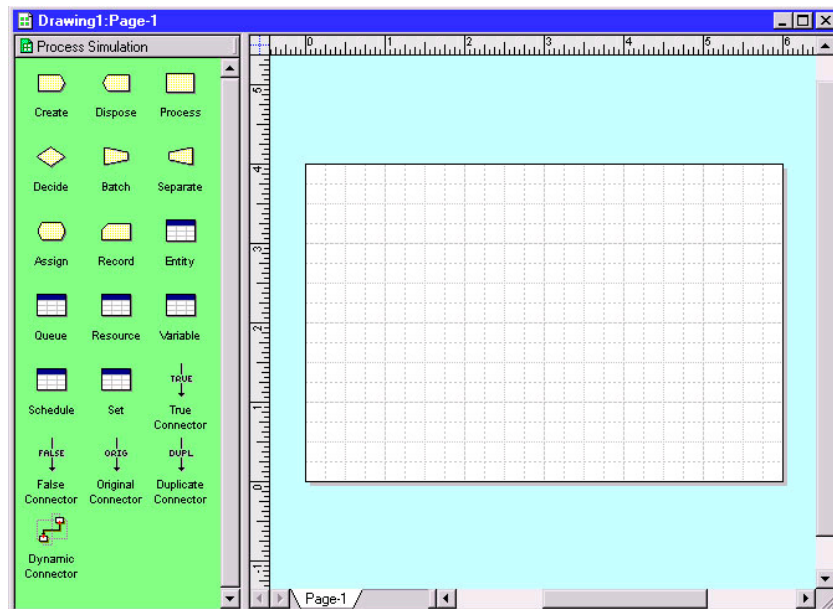
Place and connect shapes

To define the process flow portion of your model, drag and drop flowchart shapes (e.g., Create, Process, Dispose) from the Process Simulation stencil into your drawing, just as you would with other standard Visio stencils. Then, use the connectors from the Process Simulation stencil to establish flow.

When connecting shapes, the Dynamic Connector is used for all except Decide and Separate, which use special connectors to determine the type of each of the two possible outgoing connections. The table below lists the shapes from which the connectors can start (e.g., the True Connector can only start at a Decide shape).

Connector	Valid Starting Shape
True Connector	Decide
False Connector	Decide
Original Connector	Separate
Duplicate Connector	Separate
Dynamic Connector	Create, Process, Batch, Assign, Record

The sample flowchart below illustrates the use of these connectors, including the Dynamic Connector, which is unlabeled.

Decide shape (True and False connectors)

Separate shape (Original and Duplicate connectors)
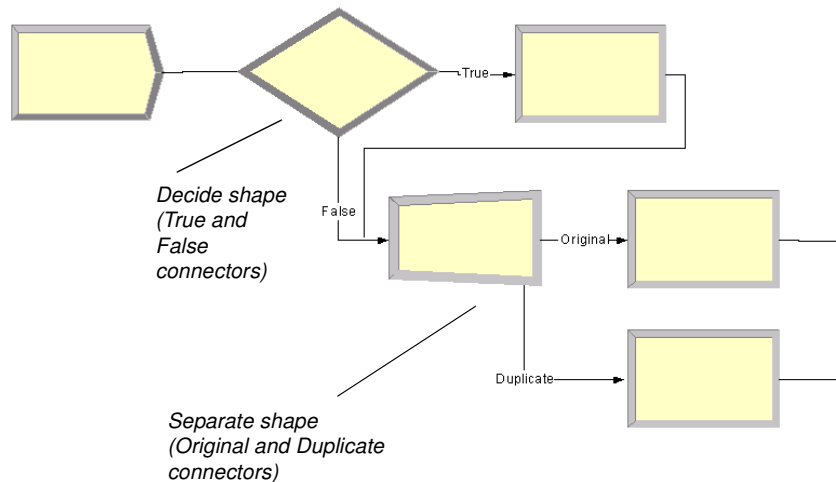
Enter custom properties

When you place shapes from the Process Simulation stencil, default names appear (e.g., Create 1, Process 1) to identify the steps in the process flow. Typically, you'll replace these names with descriptions of the process steps. To do so, simply select the shape and type the new name, as with other standard Visio shapes.

The Process Simulation stencil's shapes also provide custom dialogs for defining property values, including lists of valid options and other features to aid you in quickly characterizing process data. To open the dialog box, either double-click on the shape or right-click and select **Edit Shape Properties** from the pop-up menu, as shown below.
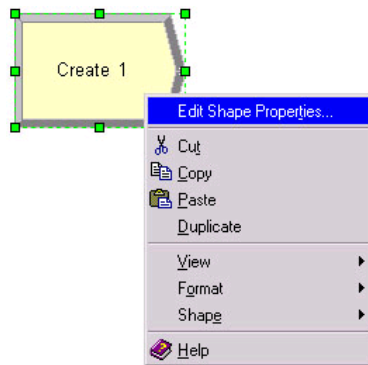
Either of these actions will display the appropriate dialog box for the shape. The dialogs that Arena presents for its corresponding modules are designed to match those in Visio, so that you're working in a familiar interface, whether mapping your process in Visio or Arena.
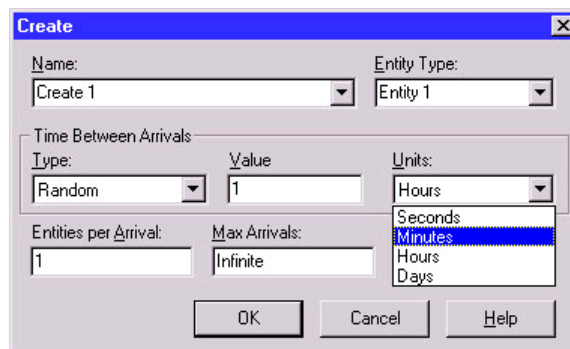
The property values that you define via the custom dialog boxes are stored with the individual shapes. When you transfer the process map to Arena, these parameters are used for simulation.

Add data shapes

To define the data modules (e.g., Entity, Resource) for the model of your process, you place shapes directly in the drawing for each of the elements you want to define. When the individual data shapes are transferred to Arena, they will not appear in the model window, but will be added to the appropriate spreadsheets instead.

For example, if processes in your flowchart are performed by resources named Clerk and Supervisor, you would place two Resource shapes and specify their characteristics (cost, capacity) by opening the property dialog boxes.

You only need to add the data shapes if you want to change any of the default values. Otherwise, they are not needed in the Visio drawing; they'll automatically be added to the spreadsheets when you transfer the drawing to Arena.

Simulate the process map in Arena

By using the Process Simulation stencil in Visio, you can define, document, and communicate your business processes. When you want to predict how your process will operate, examine it for bottlenecks, and compare possible changes to make informed decisions, you can transfer your process map from Visio to Arena, where the process will come to life with simulation and animation.

Check the drawing

While you're working with your process map, you can check it for any missing or incorrect data or connections. To check your drawing, use the **Check Drawing** item from the **Simulate** menu. After the drawing has been examined, a list of any warnings/errors is displayed, as shown below for a drawing that has a connector that is not glued at both ends.
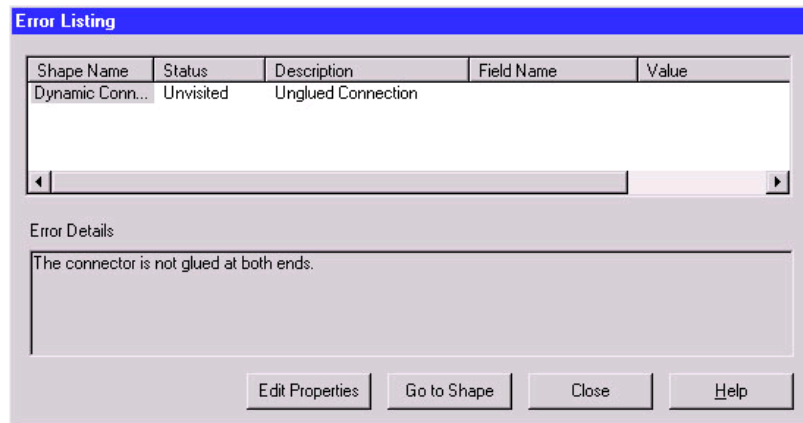
If multiple problems are detected, each will be listed with a description and, in the case of invalid or missing properties, the field and value that are improper are listed. To correct the errors in your drawing, you can use the buttons at the bottom of the dialog box. For errors in shape properties, click the **Edit Properties** button, which displays the shape's dialog box, to correct the data. In the case of connector problems, click **Go to Shape**, which displays and selects the shape that caused the problem, as shown below. (Note that the Error Listing dialog box shrinks to allow more room for viewing the drawing.)
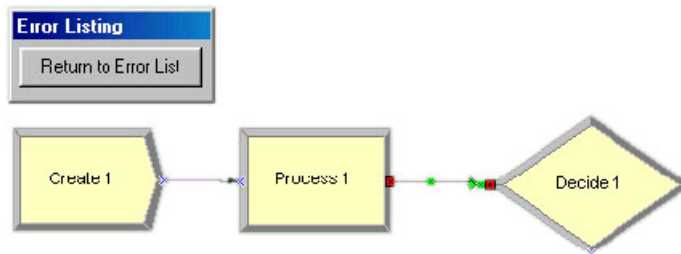
After you've corrected the problem, you can return to the list of errors/warnings by clicking the **Return to Error List** button. Once you finish correcting any additional problems, click the **Close** button. You can check your drawing at any time, correcting any or all errors that are detected.

Transfer the drawing to Arena

When you're ready to simulate your process, it's a simple matter of selecting the **Simulate Drawing** item from the **Simulate** menu. This tool opens the Arena Basic Edition and

translates your Visio process map into an Arena simulation model. When the process is complete, you have an Arena model containing modules from the Basic Process panel that mirror the shapes you used from the Visio Process Simulation stencil, including the properties and connections you specified in Visio.

In Arena, you can set the simulation run length on the **Run > Setup** page. If you do not define the run length, you can stop the simulation at any time by clicking the **Pause** button, then the **End** button.

To run the simulation, click Arena's **Go** button. Your entities will animate the flowchart as the simulation proceeds, just as if you had created the model directly in Arena. Because the process is being simulated in Arena with the standard Basic Process modules, you have all of Arena's capabilities at your disposal, including reports on all aspects of your process via the Reports panel selections.

After you have simulated your process, you can save the Arena model (*.doe*) file to continue work in Arena, or you can close it to return to Visio for continued modifications. Because the transfer of the Visio drawing is from Visio to Arena (but not vice versa from Arena to Visio), it's usually best to return to Visio. However, you might want to save the Arena model in case you want to review the simulation or results as you're refining the Visio process map.

Simulate other Visio drawings

In addition to simulating process maps using the Process Simulation add-in, you can also simulate process maps created using other Visio stencils. Arena provides a shape map editor to define the relationship between the shapes in the Visio stencils and the modules in Arena's Basic Process panel. Arena's online help describes how to use this feature, which is accessed by opening the **Tools > Options** menu and clicking on the **Visio Options** tab.

Use Visio and Arena in your organization

The combination of Visio and Arena can widen and deepen the reach of process improvement in your organization. You can exploit the accessibility of Visio to ease the transition from drawing pictures to mapping processes. All types of process constituents—from those who govern the business to the staff who execute the process—can directly influence the definition of how the process works now … and what future "to-be" operations will provide the most dramatic improvements.

Distribute the Process Simulation add-in

The Process Simulation add-in is automatically installed with Arena and is available to all Visio users, with no additional fees or licenses required. You can distribute the add-in

4 • Using Visio and Arena

throughout your organization so that everyone who has an interest in the process defini-
tion can access it directly through Visio.

With this approach, process maps can be created and shared throughout the organization
on any desktop with a Visio license. When simulation and animation are needed to visual-
ize and analyze the behavior of the process, the drawings can be transferred to systems
with the Arena Basic Edition. By using the Process Simulation template and checking the
process maps as they're created, you can be confident that taking the step to move from
static drawing to dynamic simulation will be seamless.

Publish process maps on a Web page

You can share your process maps—the drawing of your process flowchart—with others
by using Visio's HTML export feature to publish on an intranet. To save the drawing in
HTML format, select the **File > Save As** menu option in Visio and change the type to
HTML Files. (Refer to Visio's online help for more information about the HTML export
feature.)

The value of modeling and analyzing your processes can be further exploited by saving
process performance information with the process maps. The results of simulation runs
can be saved in HTML format, providing a benchmark against which actual operations or
other improvement concepts can be compared. To save the reports, click the **Export**
button when you have an Arena report open and select the **HTML** option as the file type.

A Statistical Distributions

Arena contains a set of built-in functions for generating random numbers from the commonly used probability distributions. These distributions appear on pull-down menus in many Arena modules where they're likely to be used. They also match the distributions in the Arena Input Analyzer. This appendix describes all of the Arena distributions.

Each of the distributions in Arena has one or more parameter values associated with it. You must specify these parameter values to define the distribution fully. The number, meaning, and order of the parameter values depend on the distribution. A summary of the distributions (in alphabetical order) and parameter values is given in the table below.

Summary of Arena's Probability Distributions

Distribution		Parameter Values
Beta	BETA	Beta, Alpha
Continuous	CONT	$CumP_1, Val_1, \ldots CumP_n, Val_n$
Discrete	DISC	$CumP_1, Val_1, \ldots CumP_n, Val_n$
Erlang	ERLA	ExpoMean, k
Exponential	EXPO	Mean
Gamma	GAMM	Beta, Alpha
Johnson	JOHN	Gamma, Delta, Lambda, Xi
Lognormal	LOGN	LogMean, LogStd
Normal	NORM	Mean, StdDev
Poisson	POIS	Mean
Triangular	TRIA	Min, Mode, Max
Uniform	UNIF	Min, Max
Weibull	WEIB	Beta, Alpha

To enter a distribution in an Arena field, you type the name of the distribution (or its four-letter abbreviation) followed by its parameters enclosed in parentheses. You may use spaces around punctuation to help read the distribution. A few examples appear below.

UNIF(3.5, 6)

Uniform distribution with a minimum value of 3.5, a maximum value of 6

NORMAL(83, 12.8)

Normal distribution with a mean of 83, a standard deviation of 12.8

DISCRETE(0.3,50,0.75,80, 1.0,100)

Discrete probability distribution that will return a value of 50 with probability 0.3, a value of 80 with cumulative probability 0.75, and a value of 100 with cumulative probability of 1.0. (See "Discrete probability" for a description of these parameters.)

TRIA(10, 15, 22)

Triangular distribution with a minimum value of 10, mode (most likely value) of 15, and maximum value of 22

In the following pages, we provide a summary of each of the distributions supported by Arena, listed in alphabetical order for easy reference. Each includes the density or mass function, parameters, range, mean, variance, and typical applications for the distribution.

If you have existing data and want to select the appropriate distribution for use in your model, use Arena's Input Analyzer. Click on **Tools > Input Analyzer** to launch the program, or launch it from the Windows Start menu.

Beta(β, α): BETA(Beta, Alpha)

Probability Density Function
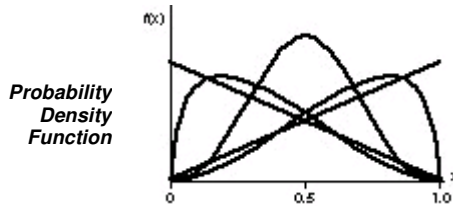
$$f(x) = \begin{cases} \dfrac{x^{\beta-1}(1-x)^{\alpha-1}}{B(\beta,\alpha)} & \text{for } 0 < x < 1 \\[2mm] 0 & \text{otherwise} \end{cases}$$

where β is the complete beta function given by

$$B(\beta, \alpha) = \int_0^1 t^{\beta-1}(1-t)^{\alpha-1}dt$$

Parameters Shape parameters Beta (β) and Alpha (α) specified as positive real numbers.

Range [0, 1] (Can also be transformed to [a,b] as described below)

Mean $\dfrac{\beta}{\beta + \alpha}$

Variance $\dfrac{\beta a}{(\beta + a)^2(\beta + a + 1)}$

Applications Because of its ability to take on a wide variety of shapes, this distribution is often used as a rough model in the absence of data. Also, because the range of the beta distribution is from 0 to 1, the sample *X* can be transformed to the scaled beta sample *Y* with the range from *a* to *b* by using the equation $Y = a + (b - a)X$. The beta is often used to represent random proportions, such as the proportion of defective items in a lot.

Continuous: CONTINUOUS(CumP$_1$, Val$_1$, . . ., CumP$_n$, Val$_n$) (c_1, x_1,. . ., c_n,x_n)

Probability Density Function

Cumulative Distribution Function
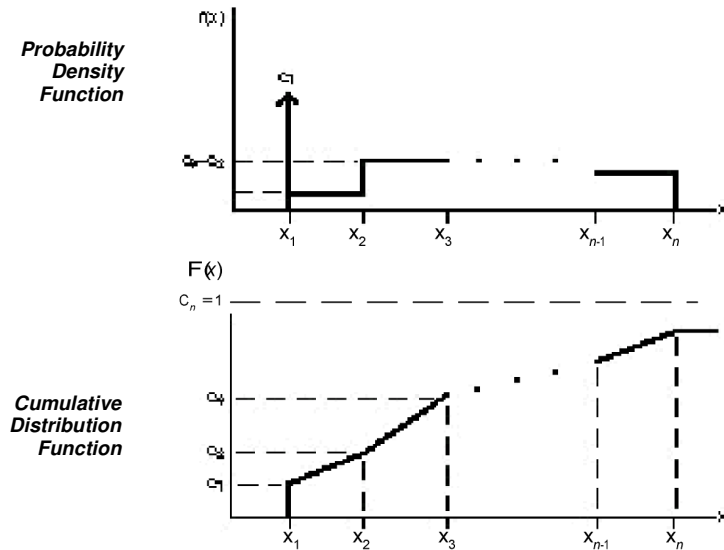
$$ f(x) = \begin{cases} c_1 & \text{if } x = x_1 \text{ (a mass of probability } c_1 \text{ at } x_1) \\ c_j - c_{j-1} & \text{if } x_{j-1} \le x < x_j, \text{ for } j = 2, 3, \ldots, n \\ 0 & \text{if } x < x_1 \text{ or } x \ge x_n \end{cases} $$

Parameters   The CONTINUOUS function in Arena returns a sample from a user-defined distribution. Pairs of cumulative probabilities c_j ($= \text{CumP}_j$) and associated values x_j ($= \text{Val}_j$) are specified. The sample returned will be a real number between x_1 and x_n, and will be less than or equal to each x_j with corresponding cumulative probability c_j. The x_j's must increase with j. The c_j's must all be between 0 and 1, must increase with j, and c_n must be 1.

The cumulative distribution function $F(x)$ is piecewise linear with "corners" defined by $F(x_j) = c_j$ for $j = 1, 2, \ldots, n$. Thus, for $j \ge 2$, the returned value will be in the interval

$(x_{j-1}, x_j]$ with probability $c_j - c_{j-1}$; given that it is in this interval, it will be distributed uniformly over it.

You must take care to specify c_1 and x_1 to get the effect you want at the left edge of the distribution. The CONTINUOUS function will return (exactly) the value x_1 with probability c_1. Thus, if you specify $c_1 > 0$, this actually results in a mixed discrete-continuous distribution returning (exactly) x_1 with probability c_1, and with probability $1 - c_1$ a continuous random variate on $(x_1, x_n]$ as described above. The graph of $F(x)$ above depicts a situation where $c_1 > 0$. On the other hand, if you specify $c_1 = 0$, you will get a (truly) continuous distribution on $[x_1, x_n]$ as described above, with no "mass" of probability at x_1; in this case, the graph of $F(x)$ would be continuous, with no jump at x_1.

As an example use of the CONTINUOUS function, suppose you have collected a set of data $x_1, x_2, \ldots, x_n$ (assumed to be sorted into increasing order) on service times, for example. Rather than using a fitted theoretical distribution from the Input Analyzer, you want to generate service times in the simulation "directly" from the data, consistent with how they're spread out and bunched up, and between the minimum x_1 and the maximum x_n you observed. Assuming that you don't want a "mass" of probability sitting directly on x_1, you'd specify $c_1 = 0$ and then $c_j = (j - 1)/(n - 1)$ for $j = 2, 3, \ldots, n$.

Range $[x_1, x_n]$

Applications   The continuous empirical distribution is often used to incorporate actual data for continuous random variables directly into the model. This distribution can be used as an alternative to a theoretical distribution that has been fitted to the data, such as in data that have a multimodal profile or where there are significant outliers.

A • Statistical Distributions

Discrete: DISCRETE(CumP1, Val1, . . ., CumPn, Valn)
$(c_1, x_1, . . ., c_n, x_n)$

Probability Mass Function
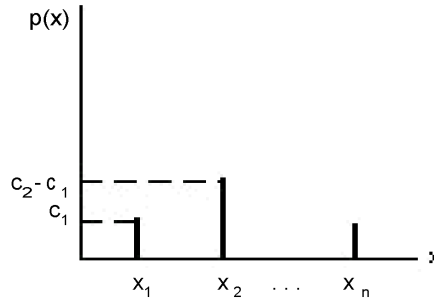
$$p(x_j) = c_j - c_{j-1}$$

where $c_0 = 0$

Cumulative Distribution Function
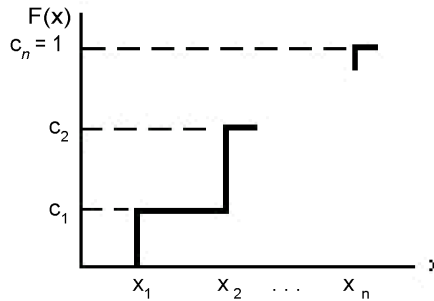
Parameters The DISCRETE function in Arena returns a sample from a user-defined discrete probability distribution. The distribution is defined by the set of n possible discrete values (denoted by $x_1, x_2, . . . , x_n$) that can be returned by the function and the cumulative probabilities (denoted by $c_1, c_2, . . . , c_n$) associated with these discrete values. The cumulative probability (c_j) for x_j is defined as the probability of obtaining a value that is less than or equal to x_j. Hence, c_j is equal to the sum of $p(x_k)$ for k going from 1 to j. By definition, $c_n = 1$.

Range $\{x_1, x_2, . . ., x_n\}$

Applications The discrete empirical distribution is often used to incorporate discrete empirical data directly into the model. This distribution is frequently used for discrete assignments such as the job type, the visitation sequence, or the batch size for an arriving entity.

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Erlang(β, k): ERLANG(ExpMean, k) or ERLA(ExpMean, k)

Probability Density Function
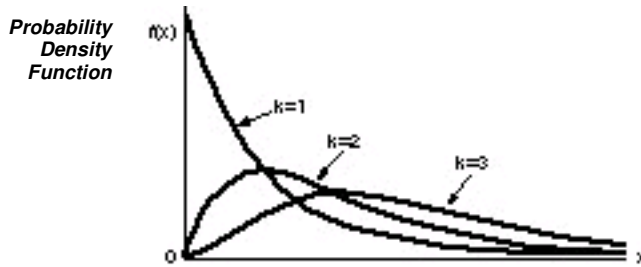
$$f(x) = \begin{cases} \dfrac{\beta^{-k} x^{k-1} e^{-x/\beta}}{(k-1)!} & \text{for } x > 0 \\ 0 & \text{otherwise} \end{cases}$$

Parameters
If X1, X2, . . . , Xk are independent, identically distributed exponential random variables, then the sum of these k samples has an Erlang-k distribution. The mean (β) of each of the component exponential distributions and the number of exponential random variables (k) are the parameters of the distribution. The exponential mean is specified as a positive real number, and k is specified as a positive integer.

Range
$[0, +\infty)$

Mean
$k\beta$

Variance
$k\beta^2$

Applications
The Erlang distribution is used in situations in which an activity occurs in successive phases and each phase has an exponential distribution. For large k, the Erlang approaches the normal distribution. The Erlang distribution is often used to represent the time required to complete a task. The Erlang distribution is a special case of the gamma distribution in which the shape parameter, α, is an integer (k).

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Exponential(β): EXPONENTIAL(Mean) or EXPO(Mean)

Probability Density Function

$$f(x) = \begin{cases} \dfrac{1}{\beta} e^{-x/\beta} & \text{for } x > 0 \\ 0 & \text{otherwise} \end{cases}$$
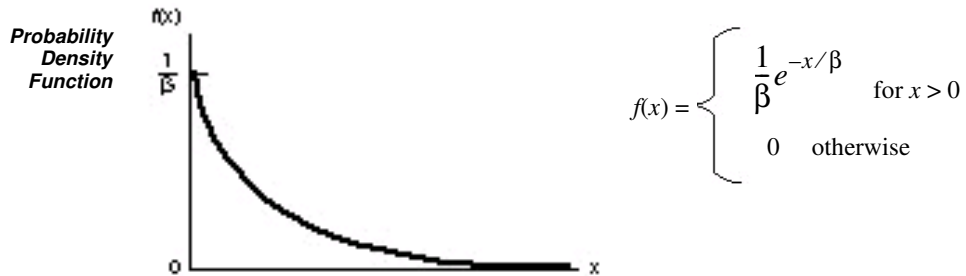
Parameters   The mean (β) specified as a positive real number.

Range $[0, + \infty)$

Mean β

Variance β^2

Applications   This distribution is often used to model inter-event times in random arrival and break-down processes, but it is generally inappropriate for modeling process delay times.

In Arena's Create module, the Schedule option automatically samples from an exponential distribution with a mean that changes according to the defined schedule. This is particularly useful in service applications, such as retail business or call centers, where the volume of customers changes throughout the day.

Gamma(β, α): GAMMA(Beta, Alpha) or GAMM(Beta, Alpha)

Probability Density Function
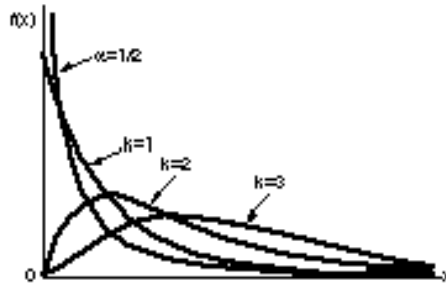
$$f(x) = \begin{cases} \dfrac{\beta^{-\alpha} x^{\alpha-1} e^{-x/\beta}}{\Gamma(\alpha)} & \text{for } x > 0 \\ 0 & \text{otherwise} \end{cases}$$

where Γ is the complete gamma function given by

$$\Gamma(\alpha) = \int_0^\infty t^{\alpha-1} e^{-1} dt$$

Parameters   Shape parameter (α) and scale parameter (β) specified as positive real values.

Range $[0, +\infty)$

Mean $\alpha\beta$

Variance $\alpha\beta^2$

Applications   For integer shape parameters, the gamma is the same as the Erlang distribution. The gamma is often used to represent the time required to complete some task (e.g., a machining time or machine repair time).

Johnson: JOHNSON(Gamma, Delta, Lambda, Xi) or JOHN(Gamma, Delta, Lambda, Xi)

Probability Density Function

Unbounded Family   *Bounded Family*
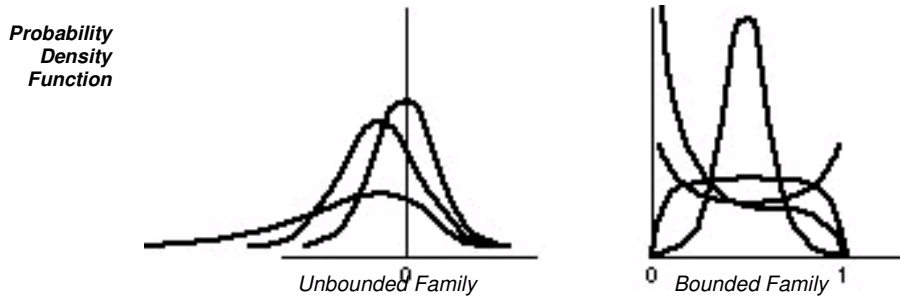
Parameters   Gamma shape parameter (γ), Delta shape parameter ($\delta > 0$), Lambda scale parameter (λ), and Xi location parameter (ξ).

Range $(-\infty, +\infty)$ Unbounded Family

$[\xi, \xi + \lambda]$ Bounded Family

Applications   The flexibility of the Johnson distribution allows it to fit many data sets. Arena can sample from both the unbounded and bounded form of the distribution. If Delta (δ) is passed as a positive number, the bounded form is used. If Delta is passed as a negative value, the unbounded form is used with $|\delta|$ as the parameter.

Lognormal(μ, σ): LOGNORMAL(LogMean, LogStd) or LOGN(LogMean, LogStd)

Probability Density Function
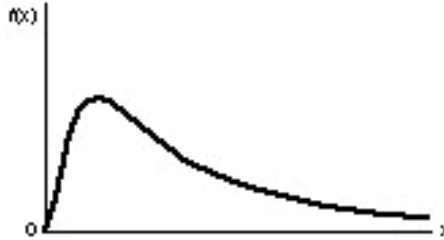
Denote the user-specified input parameters as LogMean = μ_l and LogStd = σ_l.

Then let $\mu = \ln(\mu_l^2 / \sqrt{\sigma_l^2 + \mu_l^2})$ and

$$\sigma = \sqrt{\ln\left[(\sigma_l^2 + \mu_l^2)/\mu_l^2\right]}$$

the probability density function can then be written as

$$f(x) = \begin{cases} \dfrac{1}{\sigma x \sqrt{2\pi}} e^{-(\ln(x)-\mu)^2/(2\sigma^2)} & \text{for } x > 0 \\ 0 & \text{otherwise} \end{cases}$$

Parameters Mean LogMean ($\mu_1 > 0$) and standard deviation LogStd ($\sigma_1 > 0$) of the lognormal random variable. Both LogMean and LogStd must be specified as strictly positive real numbers.

Range $[0, +\infty)$

Mean LogMean $= \mu_1 = e^{\mu + \sigma^2/2}$

Variance $(\text{LogStd})^2 = \sigma_1^2 = e^{2\mu + \sigma^2}(e^{\sigma^2} - 1)$

Applications The lognormal distribution is used in situations in which the quantity is the product of a large number of random quantities. It is also frequently used to represent task times that have a distribution skewed to the right. This distribution is related to the normal distribution as follows. If X has a lognormal (μ_1, σ_1) distribution, then ln(X) has a normal (μ, σ) distribution. Note that μ and σ are *not* the mean and standard deviation of the

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lognormal random variable X, but rather the mean and standard deviation of the normal random variable lnX.

Normal(μ, σ): NORMAL(Mean, StdDev) or NORM(Mean, StdDev)

Probability Density Function
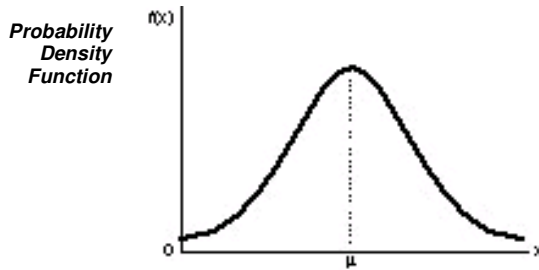
$$f(x) = \frac{1}{\sigma\sqrt{2\pi}} e^{-(x-\mu)^2/(2\sigma^2)} \text{ for all real } x$$

Parameters The mean (μ) specified as a real number and standard deviation (σ) specified as a positive real number.

Range $(-\infty, +\infty)$

Mean μ

Variance σ^2

Applications The normal distribution is used in situations in which the central limit theorem applies; i.e., quantities that are sums of other quantities. It is also used empirically for many processes that appear to have a symmetric distribution. Because the theoretical range is from $-\infty$ to $+\infty$, the distribution should only be used for positive quantities like processing times.

Poisson(λ): POISSON(Mean) or POIS(Mean)

Probability Mass Function   p(x)

$$p(x)= \begin{cases} \dfrac{e^{-\lambda}\lambda^{x}}{x!} & \text{for } x\varepsilon\,\{0,\,1,\,...\} \\[2mm] 0 & \text{otherwise} \end{cases}$$
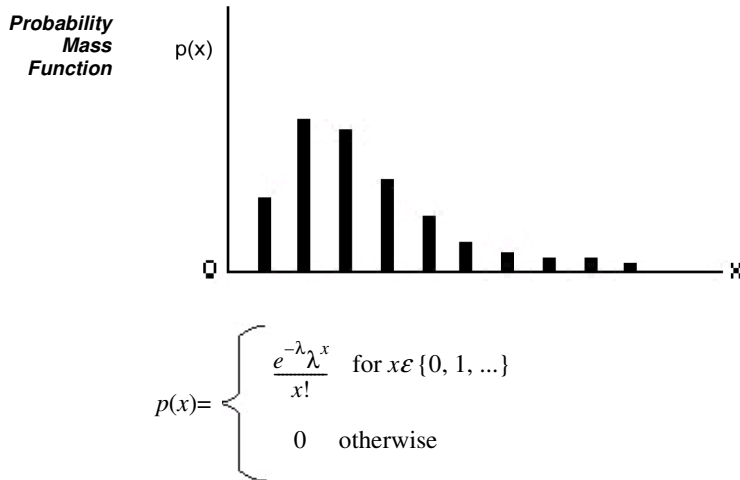
Parameters   The mean (λ) specified as a positive real number.

Range $\{0, 1,\ \ldots\}$

Mean λ

Variance λ

Applications   The Poisson distribution is a discrete distribution that is often used to model the number of random events occurring in a fixed interval of time. If the time between successive events is exponentially distributed, then the number of events that occur in a fixed-time interval has a Poisson distribution. The Poisson distribution is also used to model random batch sizes.

Triangular(*a, m, b*): TRIANGULAR(Min, Mode, Max) or TRIA(Min, Mode, Max)

Probability Density Function

$$f(x) = \begin{cases} \dfrac{2(x-a)}{(m-a)(b-a)} & \text{for } a \le x \le m \\[2ex] \dfrac{2(b-x)}{(b-m)(b-a)} & \text{for } m \le x \le b \\[2ex] 0 & \text{otherwise} \end{cases}$$
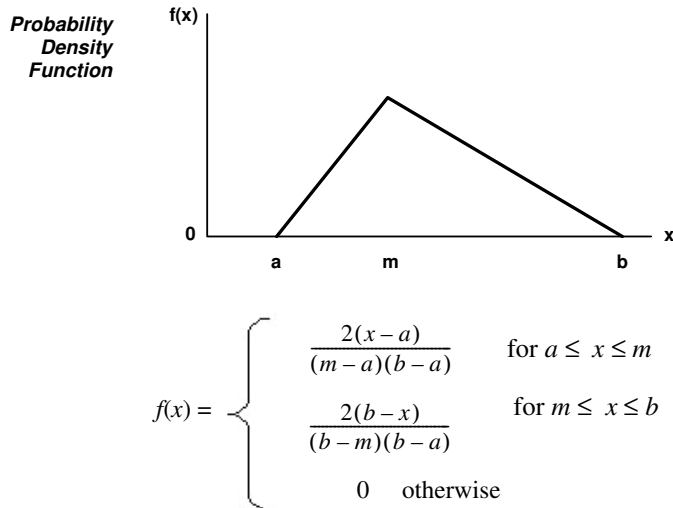
Parameters The minimum (*a*), mode (*m*), and maximum (*b*) values for the distribution specified as real numbers with $a < m < b$.

Range $[a, b]$

Mean $(a + m + b)/3$

Variance $(a^2 + m^2 + b^2 - ma - ab - mb)/18$

Applications The triangular distribution is commonly used in situations in which the exact form of the distribution is not known, but estimates (or guesses) for the minimum, maximum, and most likely values are available. The triangular distribution is easier to use and explain than other distributions that may be used in this situation (e.g., the beta distribution).

Uniform(*a, b*): UNIFORM(Min, Max) or UNIF(Min, Max)

Probability Density Function
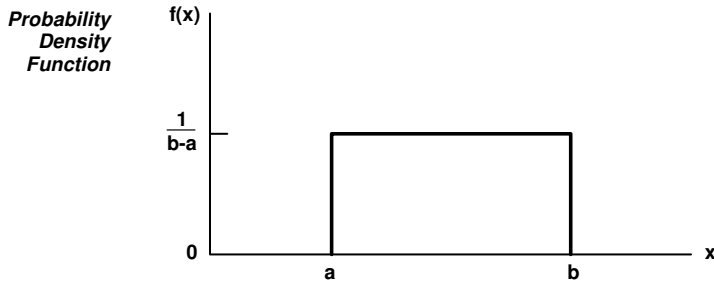
$$f(x) = \begin{cases} \dfrac{1}{b-a} & \text{for } a \le x \le b \\ \\ 0 & \text{otherwise} \end{cases}$$

Parameters   The minimum (a) and maximum (b) values for the distribution specified as real numbers with $a < b$.

Range $[a, b]$

Mean $(a + b)/2$

Variance $(b - a)^2/12$

Applications   The uniform distribution is used when all values over a finite range are considered to be equally likely. It is sometimes used when no information other than the range is available. The uniform distribution has a larger variance than other distributions that are used when information is lacking (e.g., the triangular distribution).

Weibull($\beta,\ \alpha$): WEIBULL(Beta, Alpha) or WEIB(Beta, Alpha)

Probability Density Function
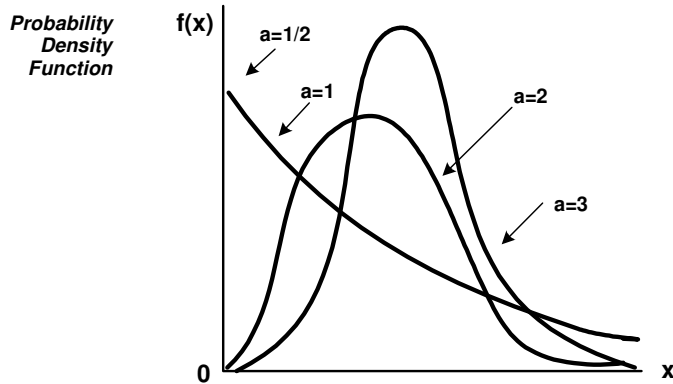
$$f(x) = \begin{cases} a\beta^{-a}x^{a-1}e^{-(x/\beta)^a} & \text{for } x > 0 \\ \\ 0 & \text{otherwise} \end{cases}$$

Parameters   Shape parameter (α) and scale parameter (β) specified as positive real values.

Range $[0, +\infty)$

Mean $\dfrac{\beta}{a}\Gamma\!\left(\dfrac{1}{a}\right)$, where Γ is the complete gamma function (see gamma distribution).

Variance $\dfrac{\beta^2}{a}\left\{2\Gamma\!\left(\dfrac{2}{a}\right) - \dfrac{1}{a}\left[\Gamma\!\left(\dfrac{1}{a}\right)\right]^2\right\}$

Applications   The Weibull distribution is widely used in reliability models to represent the lifetime of a device. If a system consists of a large number of parts that fail independently, and if the system fails when any single part fails, then the time between successive failures can be approximated by the Weibull distribution. This distribution is also used to represent non-negative task times that are skewed to the left.

B Library Shapes and Symbols

Arena *.plb* picture files

Arena's picture libraries (*.plb* files) contain images that you may use for entity, resource, and global pictures. You can use the images in these libraries for any of these three types of picture animation. You also can copy these pictures into your own libraries, draw new pictures in Arena's picture editor, or add pictures from the Arena Symbol Factory to any *.plb* file. View the online help topic "Animating Objects" to learn more about adding symbols to your picture libraries.

The Basic Process library supplies a set of default entity pictures that are preloaded into your Arena models. When you start a model, Arena adds the pictures from *BasicProcess.plb* to the entity picture list (see the **Edit > Entity Pictures** menu). Also, the predefined names associated with these pictures are added to the entity picture list (e.g., *Picture.Report*) in the Entity module and Entity picture placement dialog.

Example pictures in Basic Process.plb

Report	Bike	Airplane	Man	Woman	Blue Ball	Red Ball
Green Ball	Yellow Ball	Boat	Box	Diskette	Letter	Red Page
Blue Page	Yellow Page	Green Page	Envelope	Truck	Van	Widgets
Email	Telephone	Package	Fax			
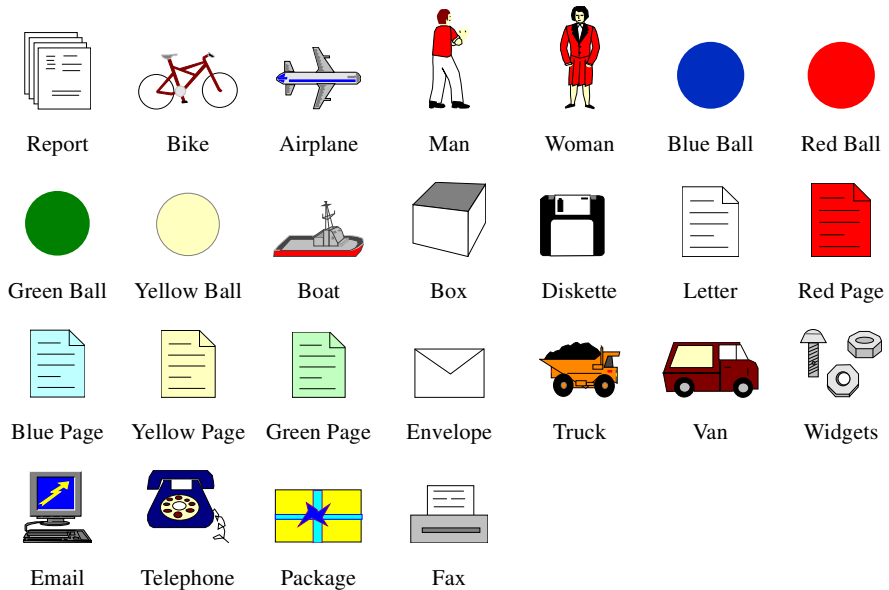
Arena .plb libraries

The list of standard Arena picture libraries includes:

- Buldings.plb
- Equipment.plb
- Faces.plb
- Factory.plb
- General.plb
- Machines.plb
- Medical.plb
- Objects.plb
- Office.plb
- Office Equipment.plb
- People.plb
- Symbols.plb
- Vehicles.plb
- Workers.plb

Common shapes may be placed from any of these categories, or they may be added from the Arena Symbol Factory or other image source by pasting from your Clipboard into a specific library. If you wish to create your own library of shapes, simply select **New** from the Entity Picture Placement window. The "Current Library" displays "(None Opened)" because the new library has not yet been named or saved. Simply select **Add** for each library shape you wish to include in your new (or existing) library file, and draw or paste the appropriate images onto the picture editor board. Remember to drag-and-drop the Ride Point to the appropriate position on your image.

Arena Symbol Factory

Arena animations can also be enhanced using Arena Symbol Factory's extensive library of over 4,000 symbols. These symbols can be used for entity, resource, transporter, or global pictures, or as graphic symbols within a model window. You can copy these images directly to the Arena model window, add them to your own libraries (*.plb* files), or add them to any of the standard Arena picture library files.

The Symbol Factory application

The Symbol Factory is launched from the main Arena toolbar by selecting **Tools > Arena Symbol Factory**. The application screen contains three distinct areas: the *Preview* pane, showing an enlarged image of the currently selected symbol; the *Categories* pane, containing the list of library symbols by groupings; and the *Symbol* pane, displaying images of all shapes contained within a selected category. An example of the application is shown below with the Machining category selected.
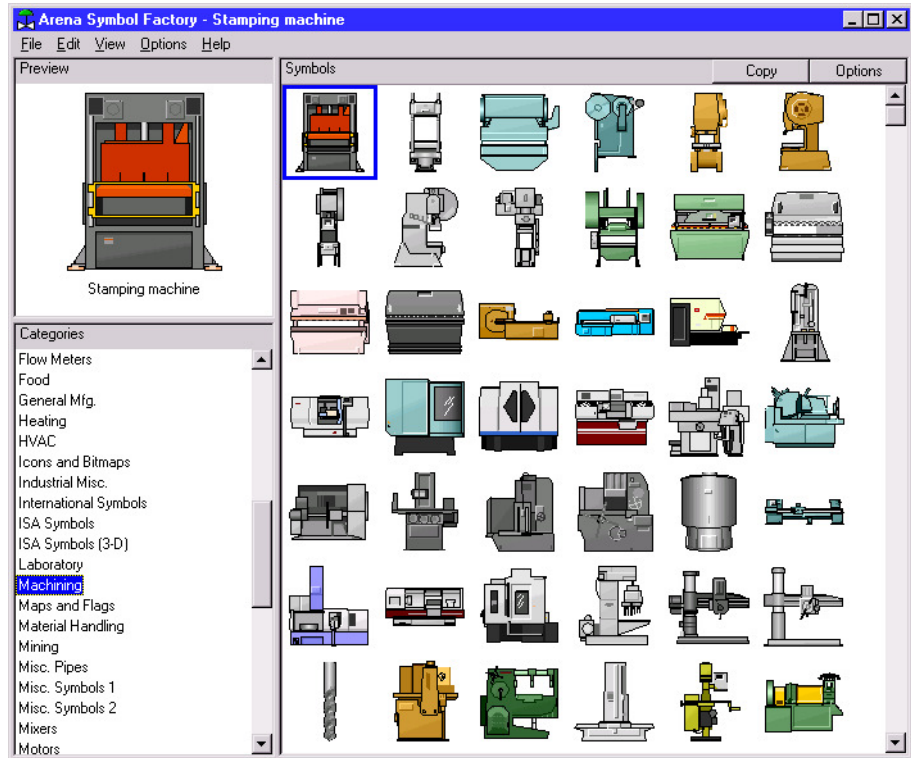
The basic operation of Symbol Factory simply requires you to select an object from a category list, click **Edit > Copy**, and then paste the symbol into your picture editor window or the Arena application window (for static shapes). Details on the Arena Symbol Factory can be found in the extensive online help embedded in the application.

You must have suitable license activation to use the full Symbol Factory capabilities. In Arena training/evaluation and run-time versions, Arena Symbol Factory is only available in demo mode. Demo mode limits use to only the first symbol in each category. New categories cannot be created, and symbols cannot be moved, added, deleted, imported, or exported in demo mode.

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