# QUESTIONS

# WORKSHEET EXAMPLE

**A Simple Model of The Carwash System**

- Vehicles arrive into a carwash shop to get a simple wash and clean up.

- The Carwash system consists of a single wash machine, which provides the actual service to the vehicles.

- Arriving vehicles join a line to wait for service. The vehicle at the head of the line is the one that is next to be serviced by the carwash machine.

- After the vehicle wash is completed, the vehicle leaves the system.

# WORKSHEET EXAMPLE

- The vehicles are considered the customers of the system, as they are the entities requesting service by the server (the wash machine).

- Figure 2.2 shows a graphical view of the conceptual model of the Carwash system.

Vehicle arrivals → Queue → Car-wash machine → Vehicle departures
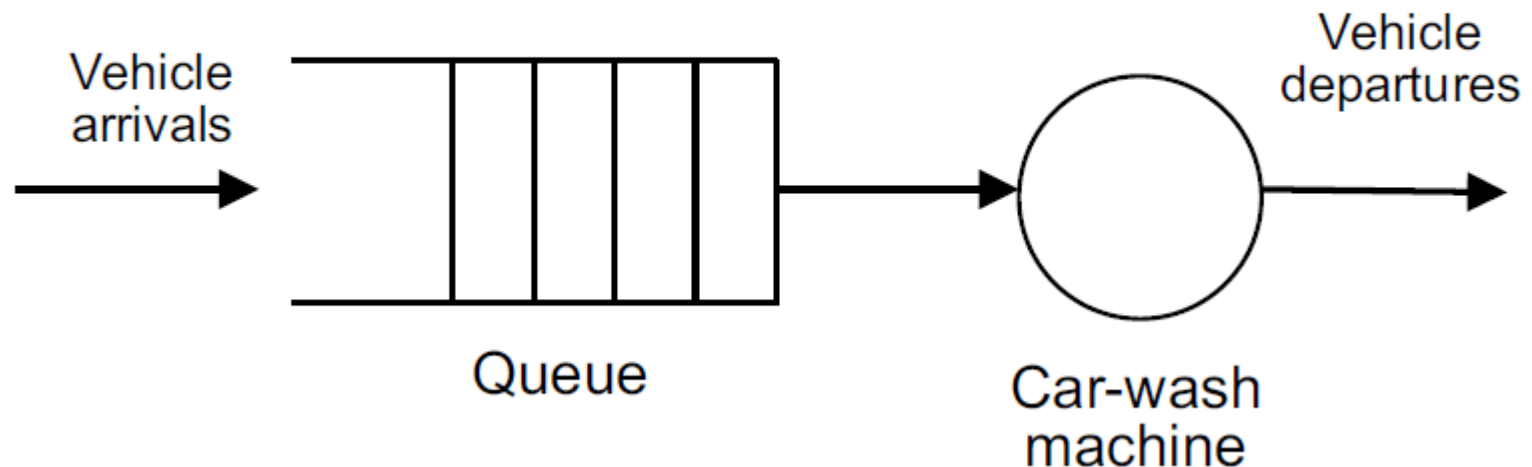
# WORKSHEET EXAMPLE

- The arrival of vehicles occurs randomly and the time between arrivals **(the inter-arrival intervals)** follow the behavior represented by an exponential probability distribution with mean value of **7.5 in minutes.**

- **Max. Arrivals:** Infinite. One car pass from the washing machines at one time.

- The service of vehicles occurs randomly and follows the behavior represented by a **normal probability distribution with mean value of 11.25 and std. dev. 1.25 in minutes.**

- The resource name is *Wash machine. (1 Machine)*

- Looking for the results of **14 hours.**

# WORKSHEET EXAMPLE-2

- **Create Module:** The entrance process is Initiate Mortgage Application. For the Entity Type, name our entities by typing Application. Inter-arrival times of jobs is exponentially distributed with a mean of 10 hour

- **Process Module:** Process name is Review Application. To define a resource to perform this process, pull down the Action list and select Seize Delay Release in Process module.

- Define a constant **16 hour** *processing delay 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.*

# WORKSHEET EXAMPLE-2

- A list of resources will appear in the center of the 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.

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

# WORKSHEET EXAMPLE-2

- ***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.***

- 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).

- 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

# WORKSHEET EXAMPLE-2

- 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.**

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

- 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.

# WORKSHEET EXAMPLE-2

- 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**

- 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.

# WORKSHEET EXAMPLE-2

- 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 also check the costing box.**

# WORKSHEET EXAMPLE-3

- **Resource button on the Animate toolbar.**

- 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.**

- 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.**

# WORKSHEET EXAMPLE-3

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.**

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.

# WORKSHEET EXAMPLE-3

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

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

- 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.

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

# WORKSHEET EXAMPLE-3

**Plot the number of applications in-process**

- 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 plot, go to the **Data Series tab page and then click the Add button.**

- 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'*

# WORKSHEET EXAMPLE-3

- 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**

- Specify the value '5' for the *Scale\Major Increment property, so that major tick marks on the y-axis is displayed every 5 units.*

- Now select the horizontal Time (X) axis. **Change the scale-related properties for that axis to be as listed below.**

- 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\Major Increment property, so that major tick marks* on the x-axis are displayed every 48 hours (or 2 days).

# WORKSHEET EXAMPLE-3

- 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.***

# WORKSHEET EXAMPLE-3

- **Small Manufacturing Problem**

### Create - Basic Process

|   | Name | Entity Type | Type | Value | Units | Entities per Arrival | Max Arrivals | First Creation |
|---|------|-------------|------|-------|-------|---------------------|--------------|----------------|
| 1 | Part 1 Arrives to System | Part 1 | Random (Expo) | 5 | Minutes | 1 | Infinite | 0 |
| 2 | Part 2 Arrives to System | Part 2 | Random (Expo) | 60 | Minutes | 1 | Infinite | 0.0 |

Operations depends on parts are;

- Part1 goes to Drilling Operation

- Part2 goes to Wrapping Operation

### Process - Basic Process

|   | Name | Type | Action | Priority | Resources | Delay Type | Units | Allocation | Minimum | Value | Maximum | Std Dev | Report Statistics |
|---|------|------|--------|----------|-----------|------------|-------|------------|---------|-------|---------|---------|-------------------|
| 1 | Drilling Center ▼ | Standard | Seize Delay Release | Medium(2) | 1 rows | Triangular | Minutes | Value Added | 1 | 3 | 6 | .2 | ☑ |
| 2 | Wrapping Center | Standard | Seize Delay Release | Medium(2) | 1 rows | Normal | Minutes | Value Added | .5 | 5 | 1.5 | 1 | ☑ |

# WORKSHEET EXAMPLE-3

- Set Replication length as 16 hours

| | Name | Type | Capacity | Busy / Hour | Idle / Hour | Per Use | State Set Name | Failures | Report Statistics |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Dril Press | Fixed Capacty | 1 | 5 | 8 | 0.0 | | 0 rows | ✔ |
| 2 | Wrap machine | Fixed Capacty | 1 | 2 | 3 | 0.0 | ▼ | 0 rows | ✔ |

Resource - Basic Process

# WORKSHEET EXAMPLE-4

- ASSIGN MODULE

| 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. |

# WORKSHEET EXAMPLE-4

- ASSIGN MODULE

| 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. |

# WORKSHEET EXAMPLE-4

- RECORD MODULE

| 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. |

# WORKSHEET EXAMPLE-4

- RECORD MODULE

| 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. |

# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM
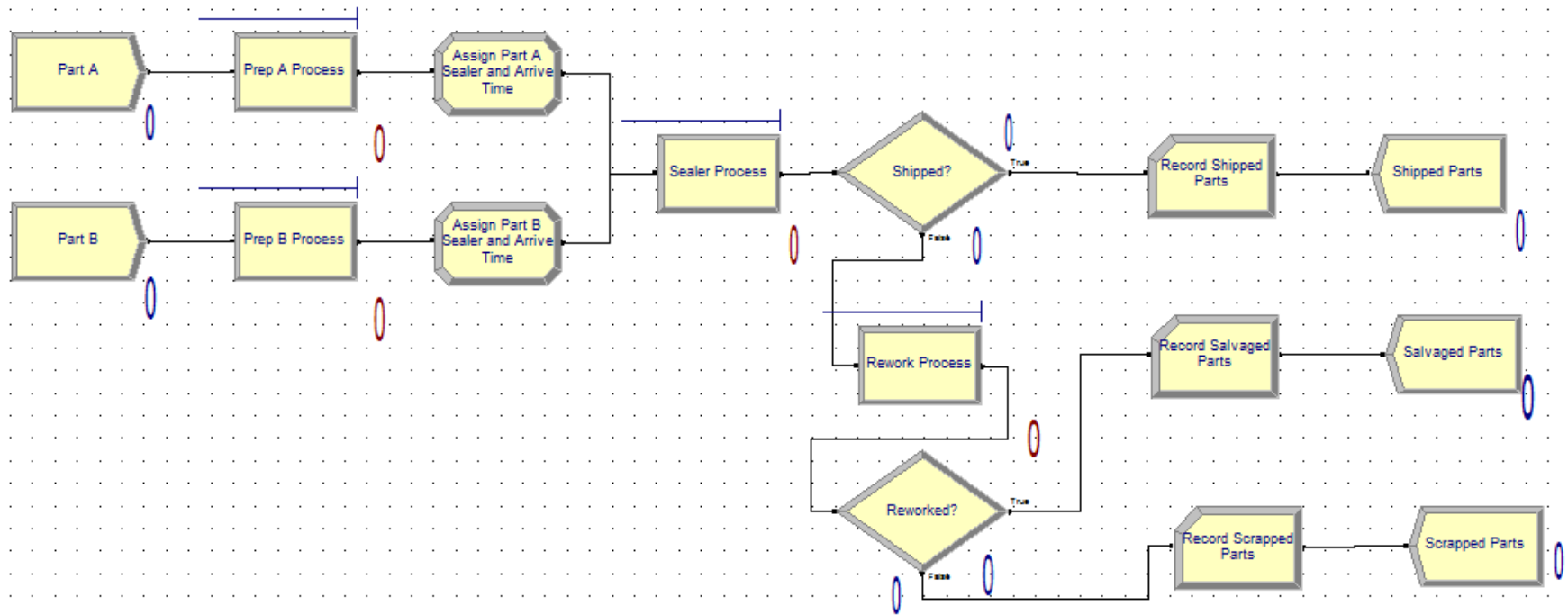
# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM

- Produce two different sealed elect. units (A, B)
- Arriving parts: cast metal cases machined to accept the electronic parts
- Part A, Part B – separate prep areas
- Both go to Sealer for assembly, testing – then to Shipping (out) if OK, or else to Rework
- Rework – Salvage (and Shipped), or Scrap

# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM

### Part A:

- Interarrivals: expo (8) minutes
- From arrival point, proceed immediately to Part A Prep area
  Process = (machine + deburr + clean) ~ tria (1,4,8) min.
- Go immediately to Sealer
  Process = (assemble + test) ~ tria (1,3,4) min.
- 91% pass, go to Shipped; Else go to Rework
- Rework: (re-process + testing) ~ expo (45)
  80% pass, go to Salvage/Ship; Else go to Scrap

# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM

## Part B:

- Interarrivals: *batches of 4, expo (25) min.*
- Upon arrival, batch separates into 4 individual parts
- From arrival point, proceed immediately to Part B Prep area
    Process = (machine + deburr +clean) ~ tria (3,5,10)
- Go to Sealer

    Process = (assemble + test) ~ weib (2.5, 5.3) min. , *different from Part A, though at same station*
- 91% pass, go to Shipped; Else go to Rework
- Rework: (re-process + test) = expo (45) min.
- 80% pass, go to Salvage/Ship; Else go to Scrap

# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM

# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM

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## INSPECTION CENTER PROBLEM

# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM



TNOW is the internal Arena variable name for the simulation clock. Other Arena variable names:

Help → Arena Help Topics → Contents →

   Using Variables, Functions, and Distributions → Variables

# WORKSHEET EXAMPLE-4

## INSPECTION CENTER PROBLEM

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## INSPECTION CENTER PROBLEM

# WORKSHEET EXAMPLE-5

**Queue Module**

- Type –specifies *queue disciplineor ranking rule*
- Shared –it this queue will be shared among several resources (more later …)
- Report Statistics –check to get automatic collection and reporting of queue length, time in queue

**Seize Module**

- Function: Used to allocate units of one or more resources to an entity.
- Operation: When an entity enters this module, it waits in a queue until all specified resources are available simultaneously. The entity can seize units of a particular resource or units of a member of a resource set.

# WORKSHEET EXAMPLE-5

**Delay Module**

- **Name—**Unique module identifier. This name is displayed on the module shape.
- **Allocation—**Type of category to which the entity's incurred delay time and cost will be added.
- **Delay Time—**Determines the value of the delay for the entity.
- **Units—**Time units used for the delay time.

**Release Module**

- The Release module is used by entities to release resources

# WORKSHEET EXAMPLE-5

- The emergency room of a small hospital operates around the clock. It is staffed by three receptionists at the reception office, and two doctors on the premises, assisted by two nurses.

- However, one additional doctor is on call at all times; this doctor is summoned when the patient workload up-crosses some threshold, and is dismissed when the number of patients to be examined goes down to zero, possibly to be summoned again later.

# WORKSHEET EXAMPLE-5

- Given Figure depicts a diagram of patient sojourn in the emergency room system, from arrival to discharge.
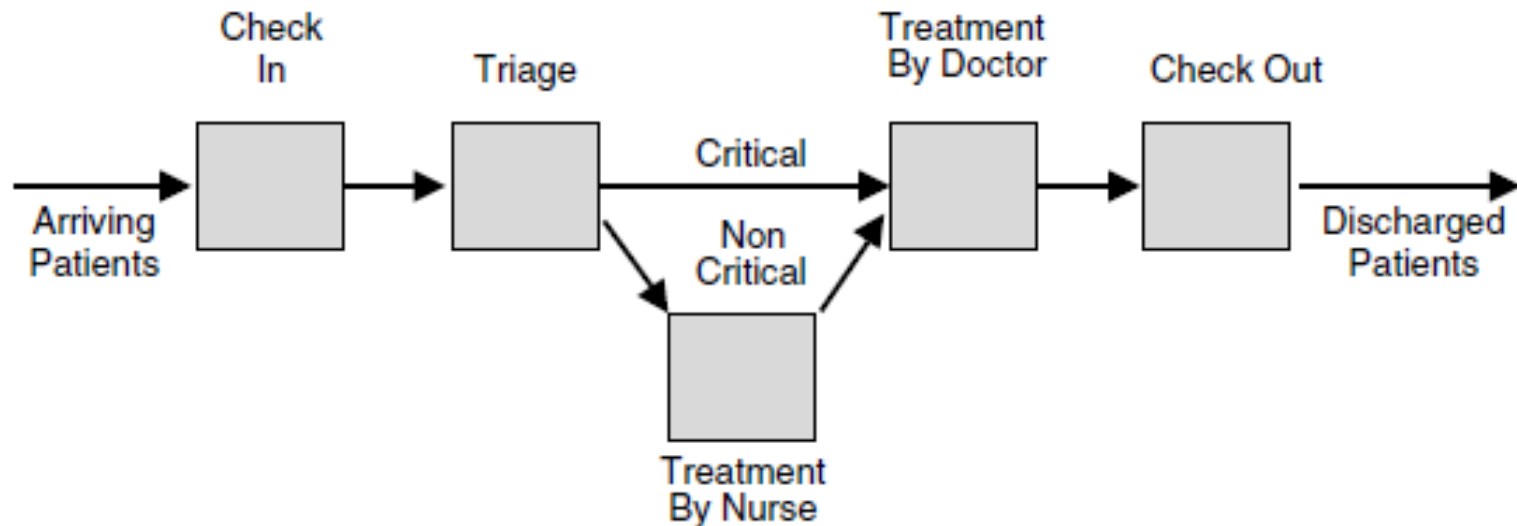
# WORKSHEET EXAMPLE-5

Patients arrive at the emergency room according to a Poisson process with mean **interarrival time of 10 minutes.**

# WORKSHEET EXAMPLE-5

An incoming patient is first checked into the emergency room by a receptionist at the reception office. **Check-in time is uniform between 6 and 12 minutes.**

# WORKSHEET EXAMPLE-5

*Since critically ill patients get treatment priority over noncritical ones, each patient first undergoes triage in the sense that a doctor determines the criticality level of the incoming patient in FIFO order. Once check-in is completed, the patient entity proceeds to the Process module, called Triage, to undergo a triage checkout by a doctor.*

The triage time distribution is **triangular with a minimum of 3 minutes, a maximum of 15 minutes, and a most likely value of 5 minutes.**

# WORKSHEET EXAMPLE-5

After the triage delay is completed, the triage doctor is released and the patient entity proceeds to determine its level of criticality. To this end, it enters the Decide module, called Critical?

It has been observed that **40% of incoming patients arrive in critical condition, and such patients proceed directly to an adjacent treatment room, where they wait FIFO to be treated by a doctor.**

# WORKSHEET EXAMPLE-5

The criticality level of patient entities is indicated in their Criticality attribute: a value of 1 codes for a critical patient, while a value of 0 codes for a noncritical patient. Accordingly, critical patient entities exiting module Critical? proceed to the Assign module, called Mark Critical, where their Criticality attribute is set to 1,

# WORKSHEET EXAMPLE-5

In contrast, patients deemed noncritical first wait to be called by a nurse who walks them to a treatment room some distance away. In contrast, noncritical patient entities are automatically marked as such, since the default value of the Criticality attribute is 0 (recall that this is the Arena convention for all attributes). Such patient entities exiting module Critical? proceed to the Seize module (In Advanced Process ) called Waiting Room,

# WORKSHEET EXAMPLE-5

Dialog boxes of the Delay modules Move to Treatment Room (left) and Treatment by Nurse (right).Once a nurse is seized, **the patient entity passes through two Delay modules, move to Treatment Room models the uniformly distributed time between 1 and 3 minutes that it takes the nurse to walk a (noncritical) patient to a treatment room, while module Treatment by Nurse models the uniformly distributed time between 3 and 10 minutes that it takes the nurse to treat a patient.**

# WORKSHEET EXAMPLE-5

At this point the paths of critical and noncritical patient entities converge, and all patient entities, both critical and noncritical, attempt to enter **the Seize module, called Wait for Doctor. Note that an individual Seize module has the same functionality as the Seize option in a Process module, but with the added flexibility that the modeler can insert extra logic between the Seize and Delay functionalities (this is impossible in a Process module). The dialog box of the Wait for Doctor module**

# WORKSHEET EXAMPLE-5

(Criticality==1)*UNIF(20,30)
+(Criticality==0)*UNIF(5,10)

Recall that the treatment duration of a patient depends on its level of criticality, namely, on its Criticality attribute

For critical patients, the duration is uniform between 20 and 30 minutes, while for noncritical ones it is uniform between 5 and 10 minutes only. This dependence is captured in the Delay Time field of Figure above by the expression
Once a doctor becomes available, the patient entity at the head of the line seizes that doctor and proceeds to the Delay module, called Treatment by Doctor The treatment time of critical patients is **uniform between 20 and 30 minutes.**

# WORKSHEET EXAMPLE-5

The checkout procedure Process module requires a patient to seize a receptionist for **a uniform time between 10 and 20 minutes, before releasing that receptionist.**

# WORKSHEET EXAMPLE-5

Finally, patient entities enter **two statistics-collecting Record modules, called Patient Sojourn Time and Patient Departures, respectively, whose dialog boxes are depicted in Figure below**

# WORKSHEET EXAMPLE-5

Each row in the spreadsheet specifies a queue in the Arena model, while columns Type and Attribute Name specify jointly the queueing discipline. Observe that all rows, except row 4, specify the ordinary FIFO discipline, while row 4 implicitly specifies the FIFO within priority classes discipline. More specifically, patient entities in Wait for Doctor.Queue queue up FIFO, but their queueing priority is determined by their Criticality attribute (**the higher the value of Criticality, the higher the priority).**

**24 HOUR REPLICATION LENGTH**