Investigación Operativa

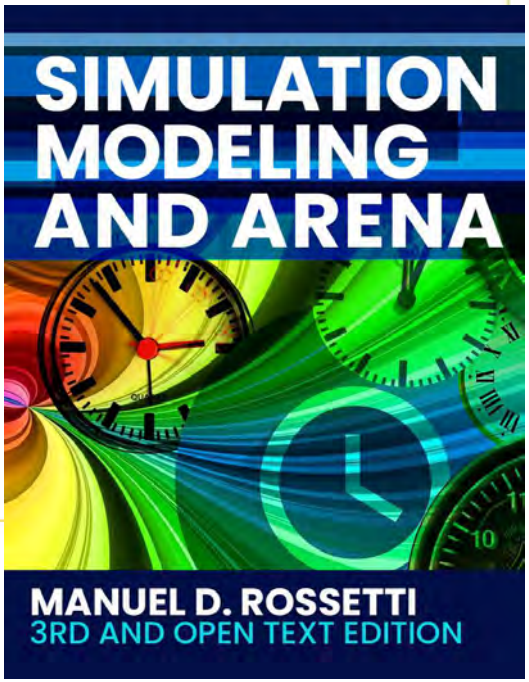
Operations Research

Introduction to ARENA

Departamento de Organización Industrial

September 1, 2023

https://rossetti.github.io/RossettiArenaBook/



1. ARENA Basics
2. Example: The Pharmacist
3. Extended Example: The Pharmacist Continued

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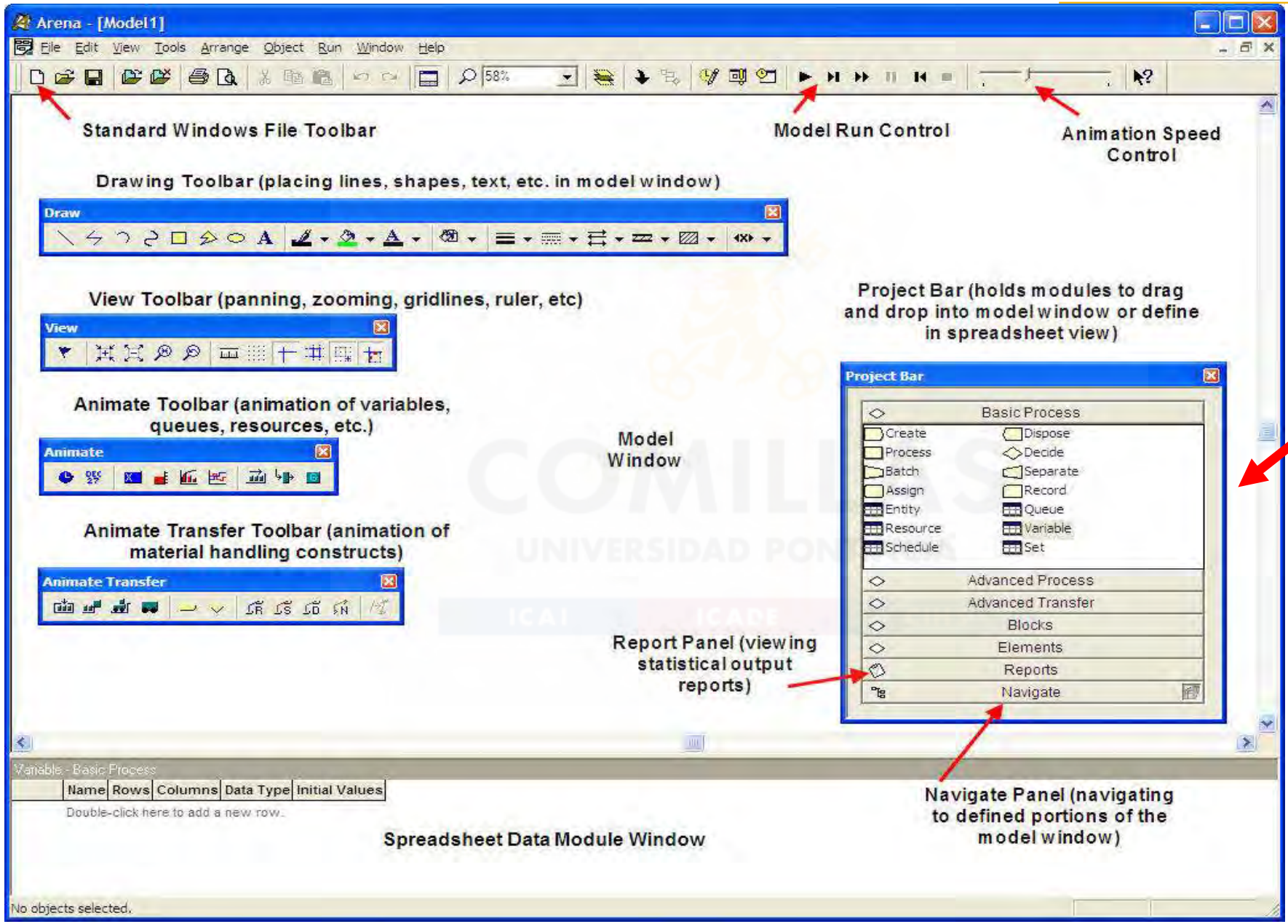
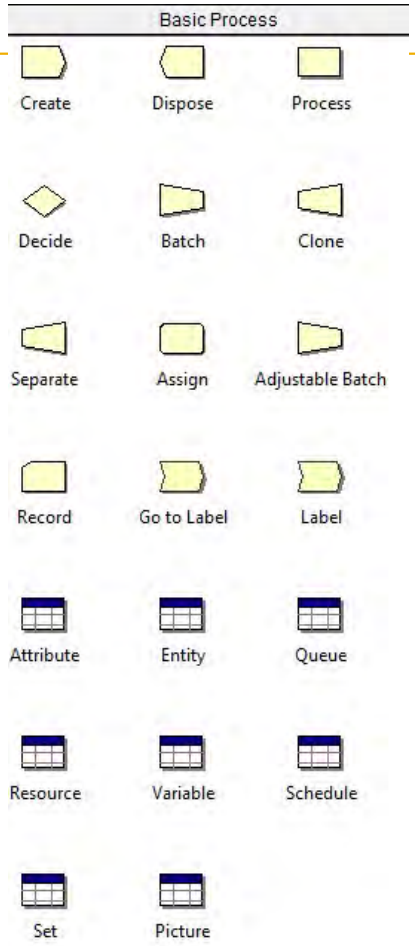
ARENA Basics

Arena Environment



Modules:
CREATE
PROCESS
DISPOSE
...

Processing Entities: Basic Process/Data Modules (i)



Basic Process templates:

- **CREATE:** To create entities that pass through the model
- **DISPOSE:** To dispose the entities
- **PROCESS**: Set of activities experienced by an entity
  - **Delay** (Delay entity for the service/activity; no recourse needed)
  - **Seize Delay Release** (Seize resource; delay for the service/activity; release resource)
- **DECIDE**: Direct the entity through the system by probabilistic and conditional mechanisms (if/else; while).

Basic Data templates:

- **Entity:** It is possible to create specific entities (not just generic)
- **Resource**: Define the resources of your problem.
- **Variable/Attribute**: Define state variables or Define entity attributes
- **Queue**: Queue of entities that form in front of processes.

Creating and Disposing of Entities in ARENA

- CREATE module: the way to introduce entities into a model

Time Between Arrivals

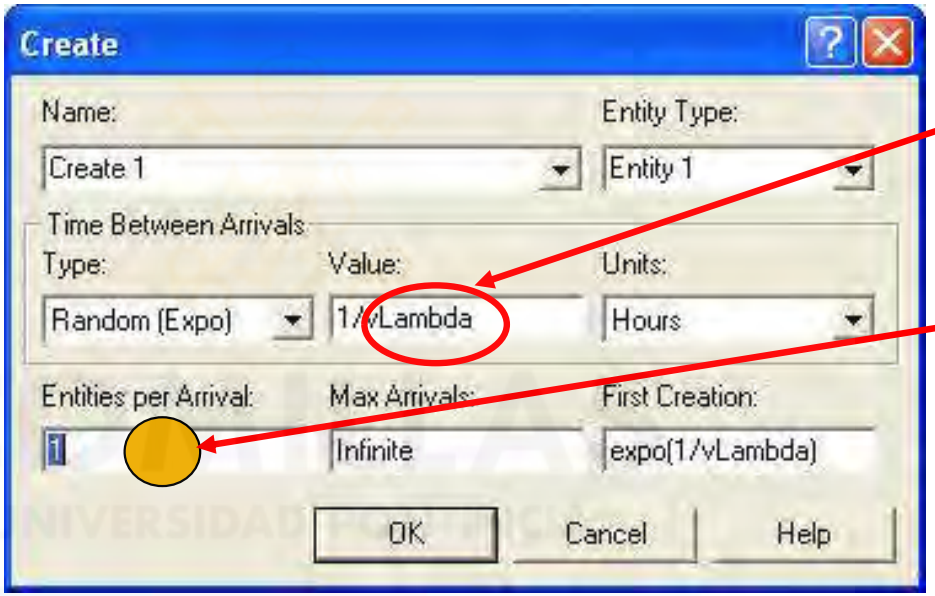
Types:

Random: Uses an Exponential distribution

Schedule: Nonhomogenous Poisson process with rates specified by Schedule module

Constant: Constant time

Expression: List of distributions or expressions:
Normal, Triangular, Beta, …



Arrival rate as a Variable

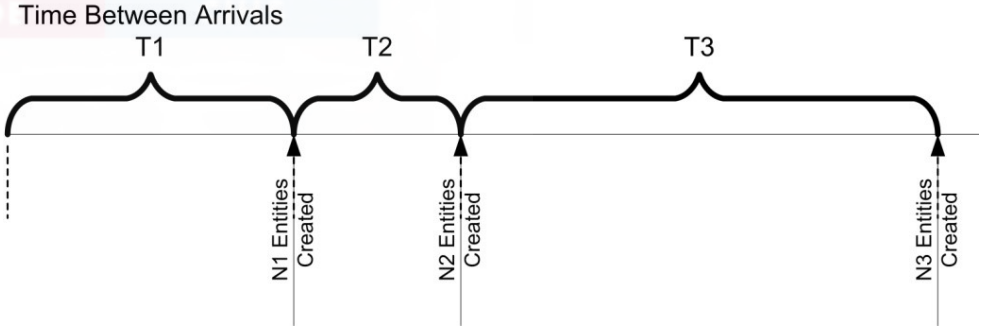
Compound arrival:

Disc(0.2,1, 0.5, 2, 1.0,3)

20% arrival of 1
30% arrival of 2
50% arrival of 3

Entities per Arrival: Number of entities that will enter the system at a given time with each arrival

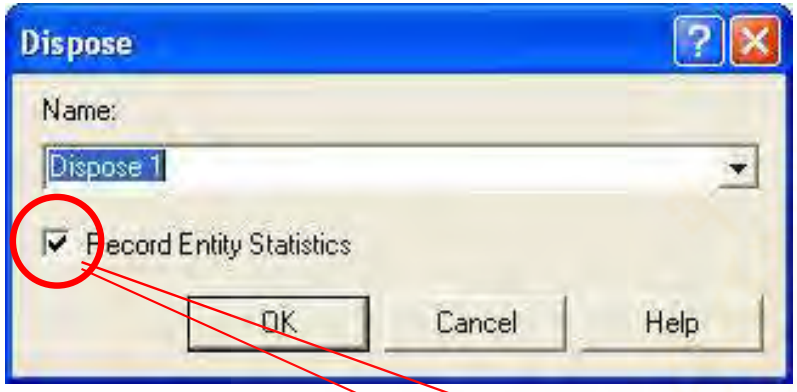
Max Arrivals: Maximum number of arrival events allowed by the module. It is useful to limit the number of entities flowing through the model.



First Creation: Starting time for the first entry to arrive at the system (not applied when the Type is Schedule)

Creating and Disposing of Entities in ARENA

- DISPOSE module: the entities that come into this module leave the model



Time Statistics:

Value Added Time (VA Time)

Non-Value Added Time (NVA Time)

Wait Time

Total Time

...

Cost Statistics:

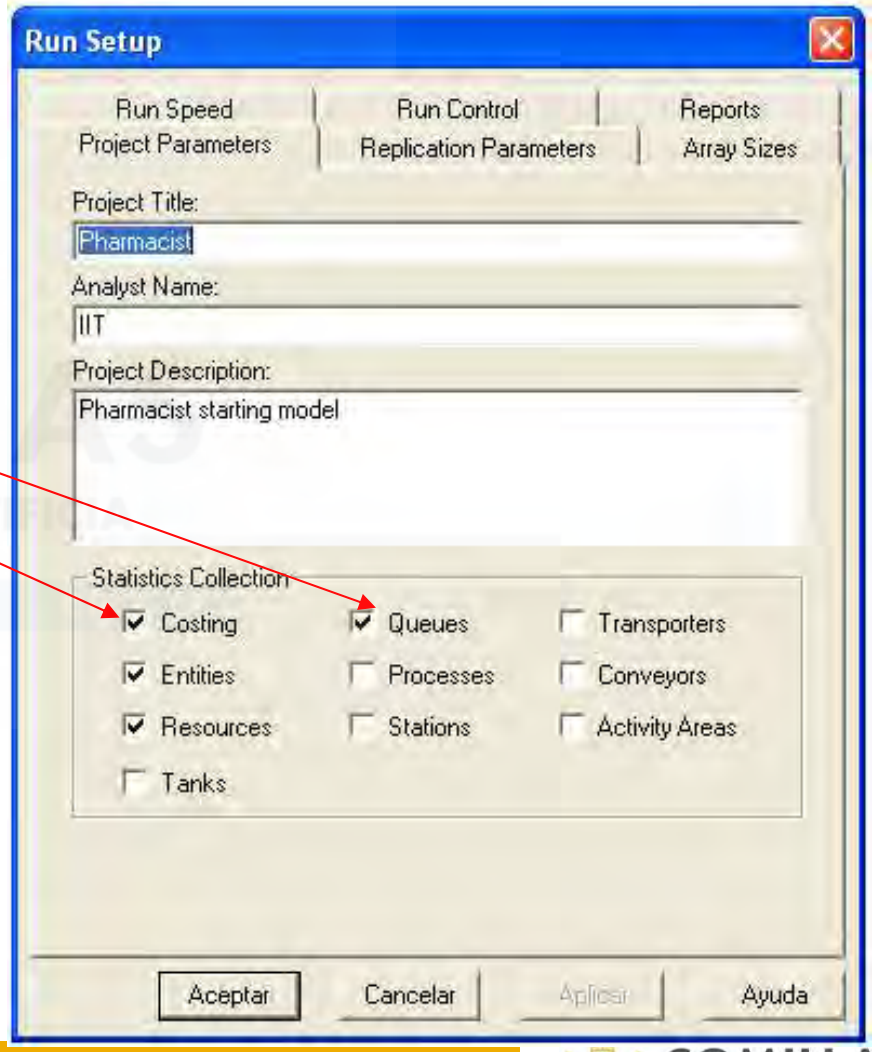
Value Added Cost (VA Cost)

Non-Value Added Cost (NVA Cost)

Wait Cost

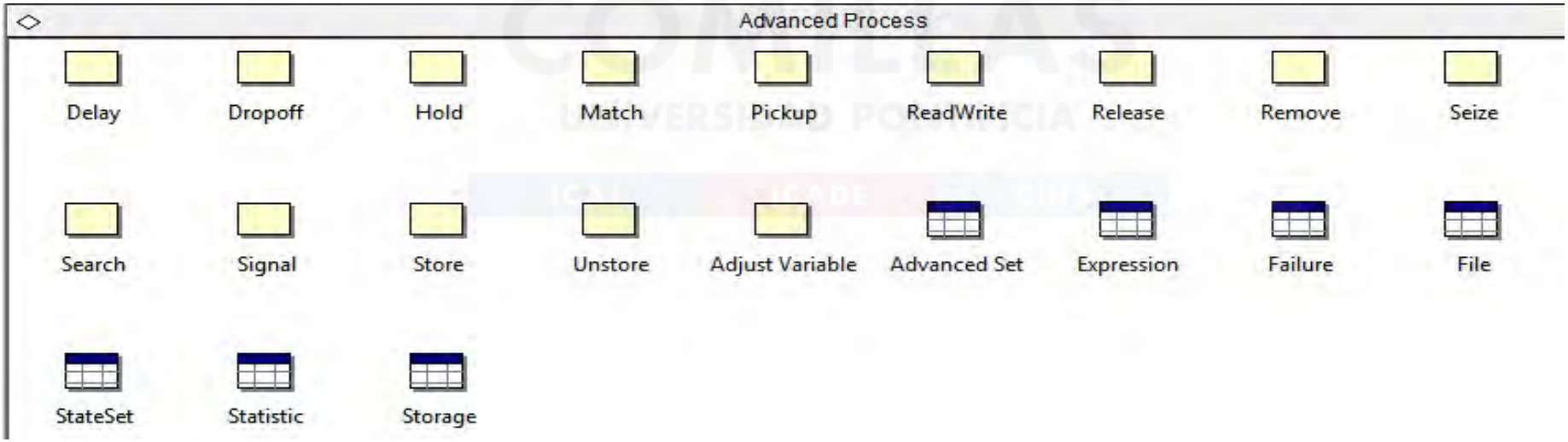
Total Cost,...

Run > Setup > Project Parameters



Processing Entities: Basic/Advanced Process Modules (ii)

- SEPARATE / BATCH: To duplicate or combine entities in a model
- ASSIGN: To change/update/initialize the value of various attributes and variables
- READWRITE / FILES: To handle inputs and outputs in a model
- RECORD / STATISTIC: To collect statistics in a module



1. ARENA Basics
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3. Extended Example: The Pharmacist Continued

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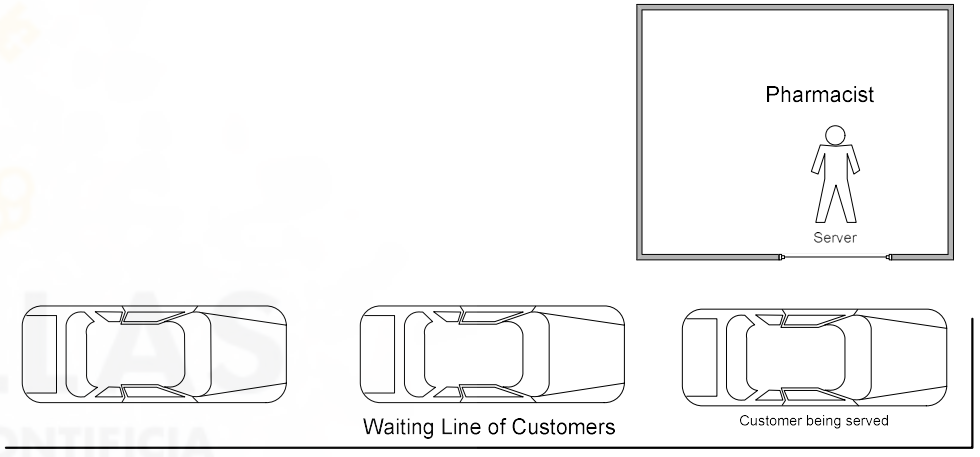
Example 1: The Pharmacist

A demo example

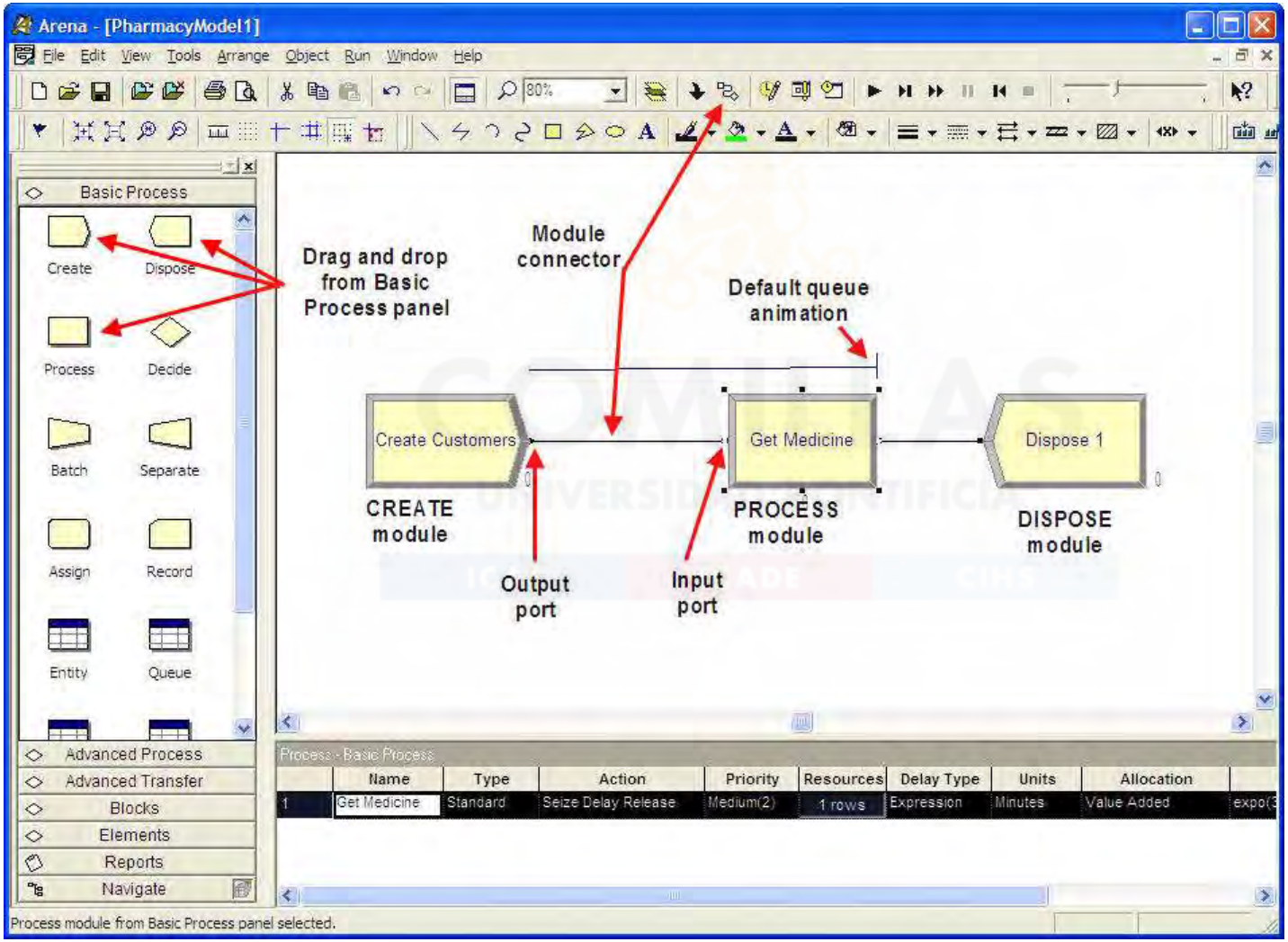
- Customers arrive at a drive-through pharmacy window according to a Poisson distribution with a mean of 10 customers per hour.
- The time it takes the pharmacist to serve the customer is random, and data indicate that the time is well modeled with an exponential distribution with a mean of 3 minutes.
- Customers who arrive at the pharmacy are served in the order of arrival, and we assume that enough space is available within the parking area to accommodate any waiting customers.



File: Pharmacist_chapter_1.doe

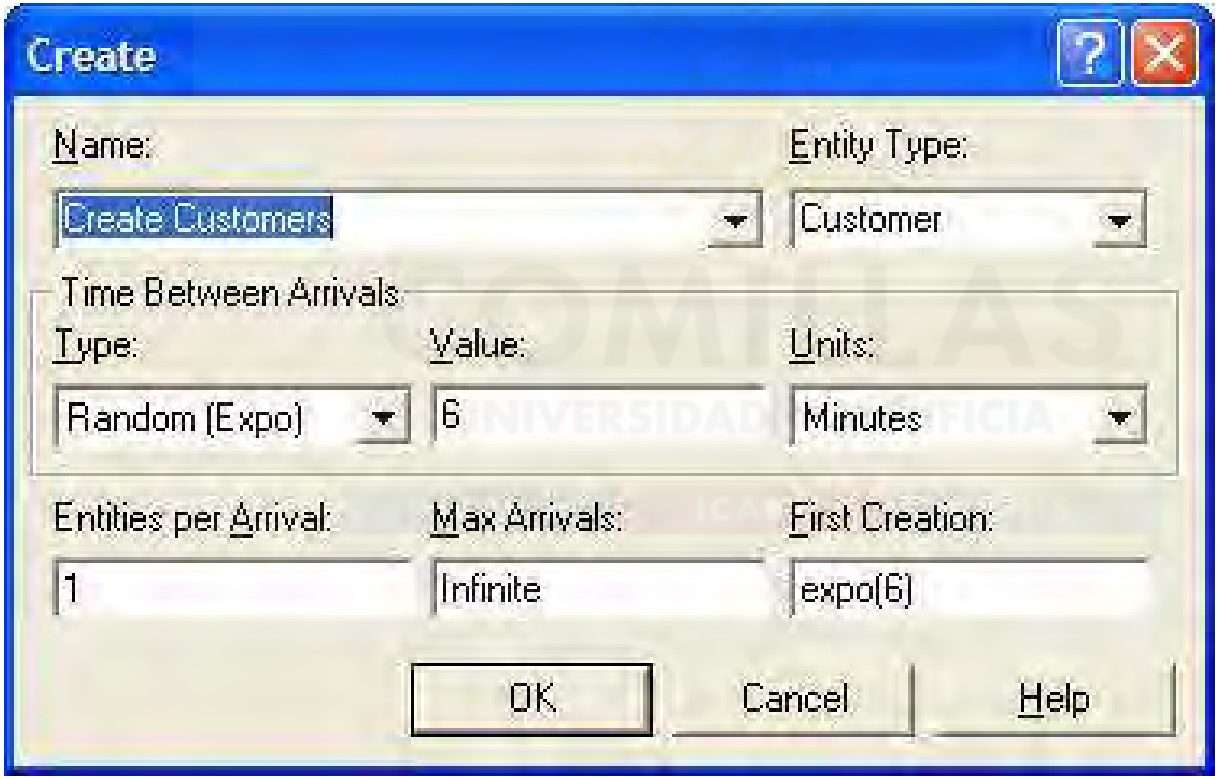
Implementing the demo model in Arena (i)

- Using the *Basic Process Panel Template*, drag the CREATE, PROCESS and DISPOSE into the model window, and connect them via the module connector.



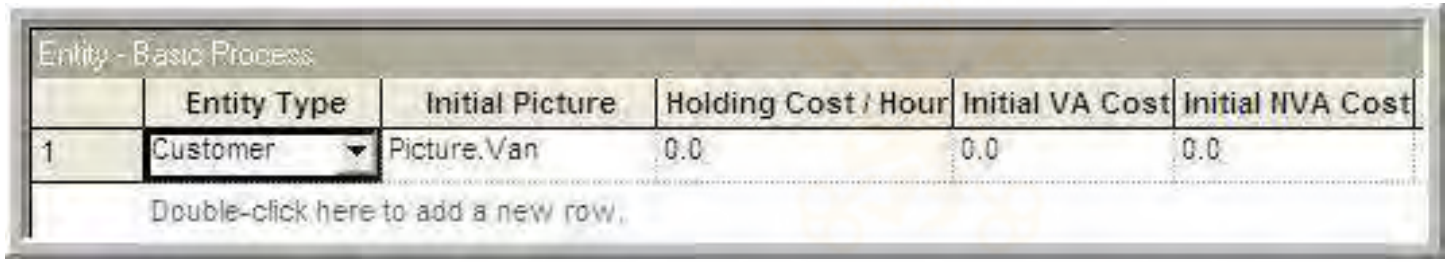
Implementing the demo model in Arena (ii)

- *Arrival Process*
  - CREATE module: Poisson process with an arrival rate of 10 customers per hour (6 minutes between two consecutive arrivals)
  - Double-click on the icon to show its module panel and include parameters

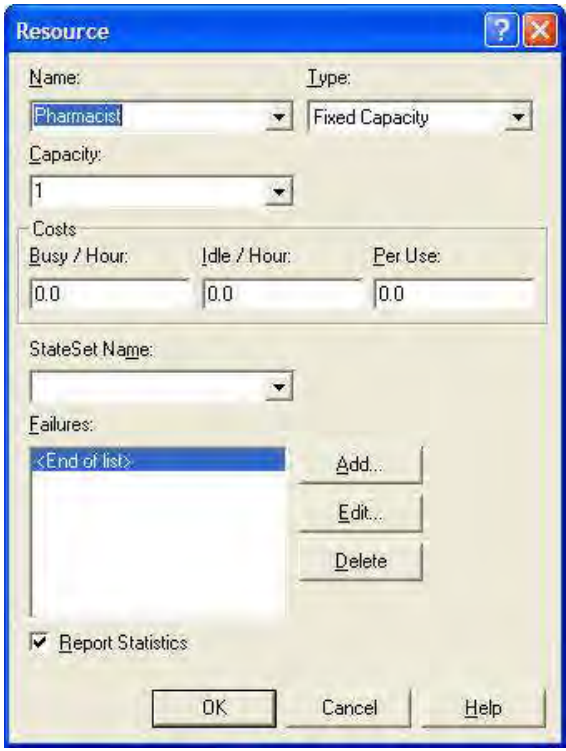


Implementing the demo model in Arena (iii)

- *ENTITY module*
  - ENTITY: Elements that flow through the system (pharmacist's customers)
  - Add a new entry using the double-click in the spreadsheet window
  - Associate a picture to the entity

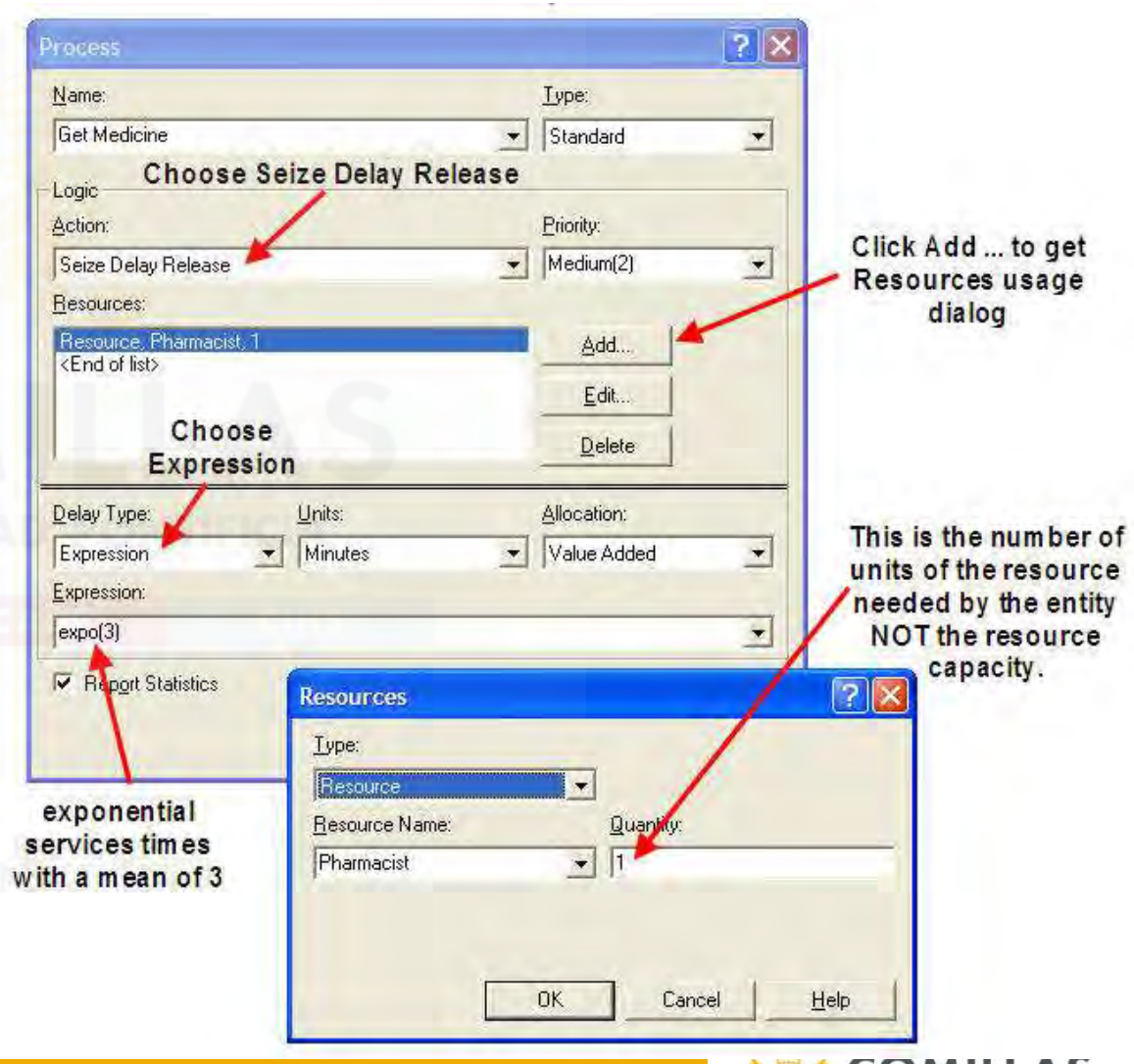


- *RESOURCE module*
  - An element demanded by entities with finite capacity
  - Edit the new entry by clicking the spreadsheet window



Implementing the demo model in Arena (iv)

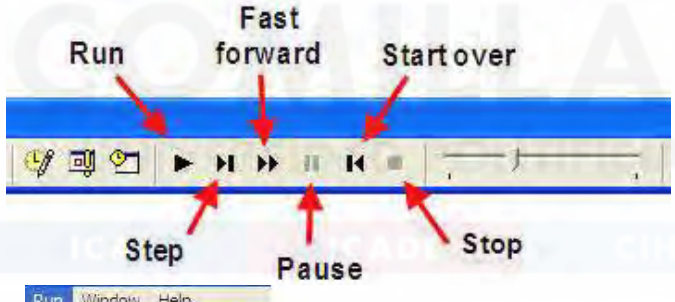
- *PROCESS module*
  - PROCESS: Set of activities experienced by an entity
  - Processes may be resource-unconstrained or constrained (example)
  - Pharmacist's example:
    - **Seize** the pharmacist
    - **Delay** in the service
    - **Release** the pharmacist

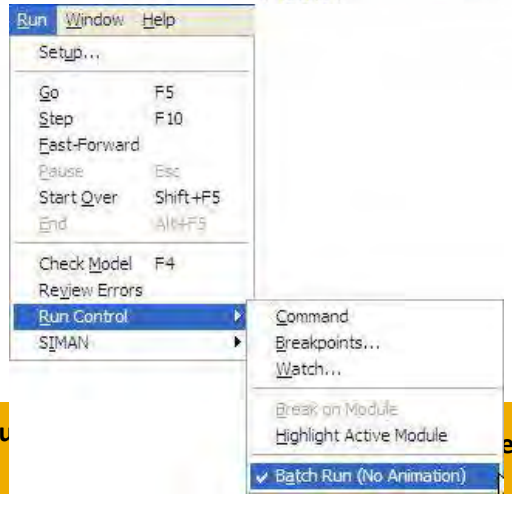


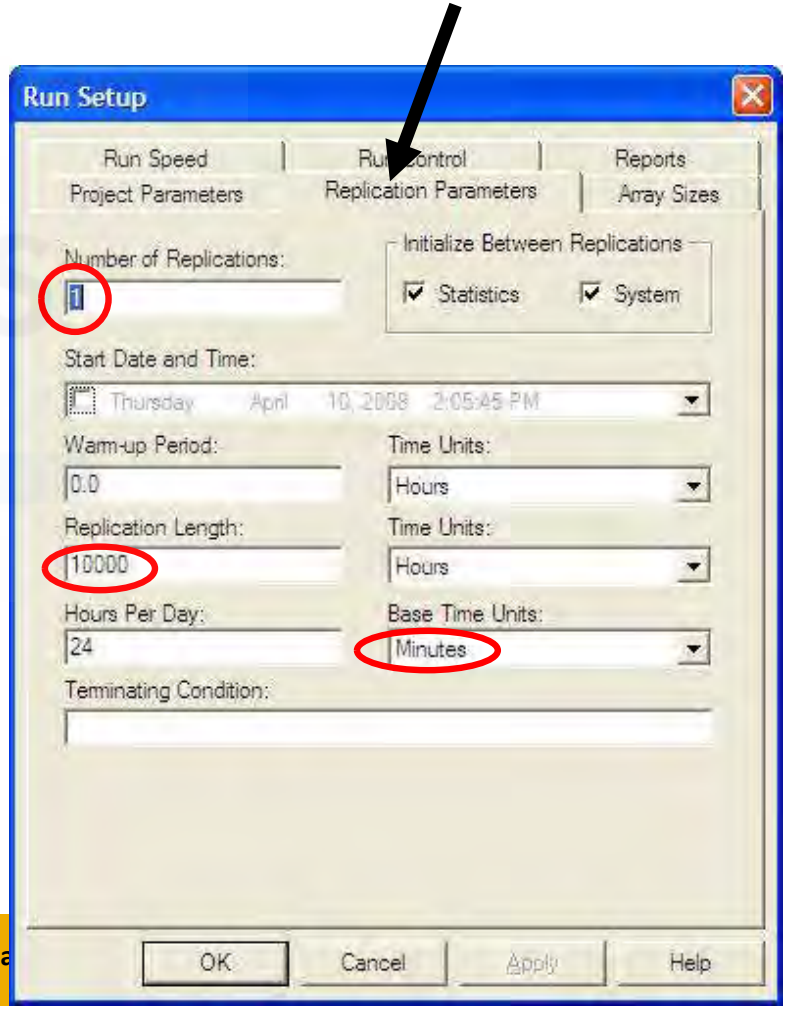
Implementing the demo model in Arena (v)

- *RUN Setup*
  - Assumptions:
    - The pharmacy is open 24 hours a day, 7 days a week
    - The arrival process does not vary over time
    - Simulation time: 10,000 hours of operation
    - Go to the *Run* menu item and choose *Setup*
    - The base time units are minutes for output reports
    - To run the model:
      - *Run* menu item
      - Run toolbar

Fast forward:
Run without animation (Batch mode)
Start over:
Stops the run and starts it again
Animation slider:
To slow down or speed up

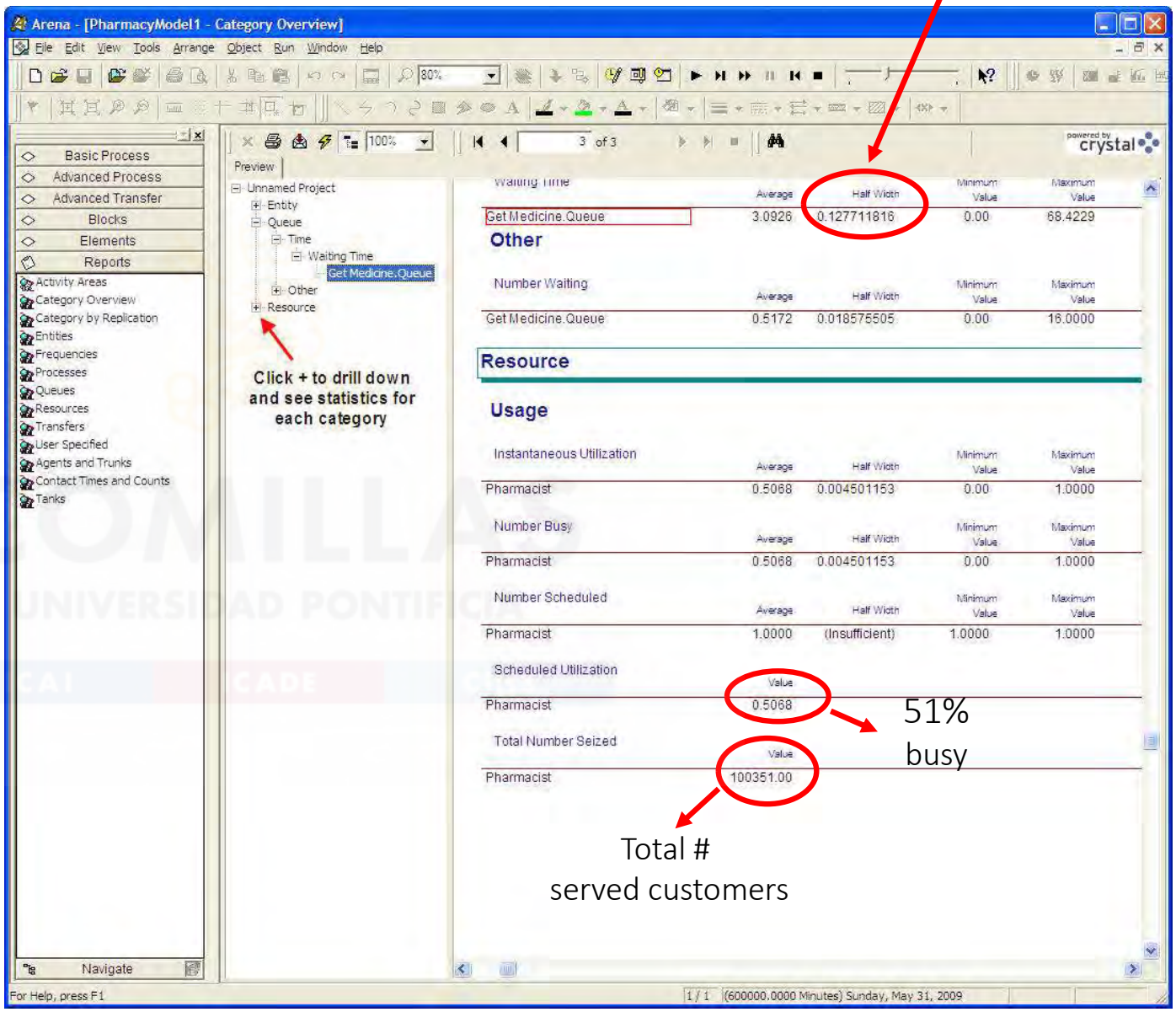






Implementing the demo model in Arena (vi)

- *ANALYZE Results*
  - Report Viewer:



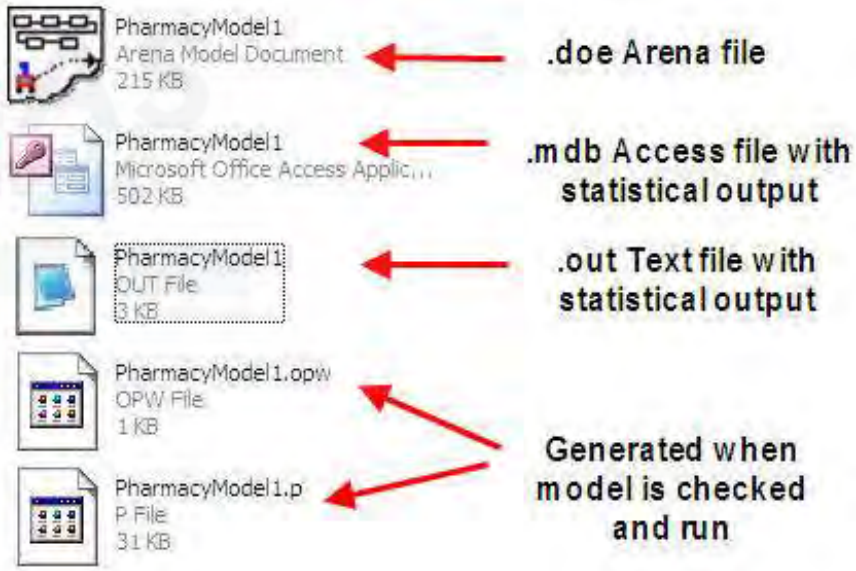
Implementing the demo model in Arena (vii)

- *ANALYZE Results (cont.)*
  - Text-based report: the file "modelname.out" in the directory associated to the model

PharmacyModel1 - Notepad

File Edit Format View Help

```
                                ARENA Simulation Results
                                Industrial Engineering

                                Summary for Replication 1 of 1

Project: Unnamed Project                                  Run execution date : 4/10/2008
Analyst:                                                  Model revision date: 4/10/2008

Replication ended at time      : 600000.0 Minutes
Base Time Units: Minutes

                                        TALLY VARIABLES

Identifier                      Average   Half Width  Minimum    Maximum   Observations
-------------------------------------------------------------------------------------
Customer.VATime                 3.0301    .02175      2.0142E-05 37.451    100350
Customer.NVATime                .00000    .00000      .00000     .00000    100350
Customer.WaitTime               3.0926    .12771      .00000     68.422    100350
Customer.TranTime               .00000    .00000      .00000     .00000    100350
Customer.OtherTime              .00000    .00000      .00000     .00000    100350
Customer.TotalTime              6.1227    .14416      2.0142E-05 70.525    100350
Get Medicine.Queue.WaitingTime  3.0925    .12771      .00000     68.422    100351

                                DISCRETE-CHANGE VARIABLES

Identifier                      Average   Half Width  Minimum    Maximum   Final Value
-------------------------------------------------------------------------------------
Customer.WIP                    1.0240    .02218      .00000     17.000    1.0000
Pharmacist.NumberBusy           .50679    .00450      .00000     1.0000    1.0000
Pharmacist.NumberScheduled      1.0000    (Insuf)     1.0000     1.0000    1.0000
Pharmacist.Utilization          .50679    .00450      .00000     1.0000    1.0000
Get Medicine.Queue.NumberInQueue .51724   .01858      .00000     16.000    .00000

                                OUTPUTS

Identifier                      Value
-------------------------------------------------
Customer.NumberIn               1.0035E+05
Customer.NumberOut              1.0035E+05
Pharmacist.NumberSeized         1.0035E+05
Pharmacist.ScheduledUtilization .50679
System.NumberOut                1.0035E+05

Simulation run time: 0.02 minutes.
Simulation run complete.
```



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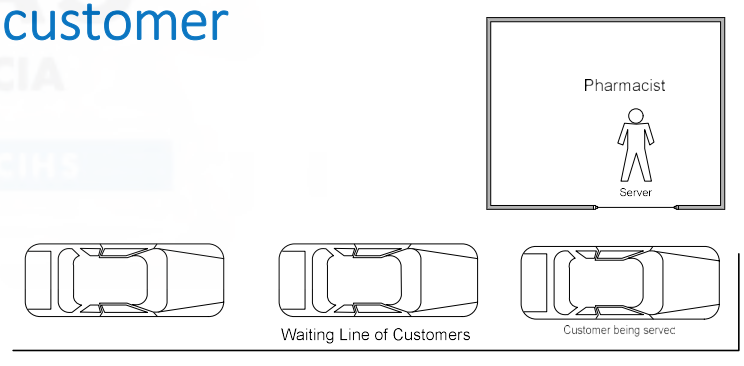
Extended Example: The Pharmacist Continued

Extending/modifying the demo example

- Compound Arrivals: 20% 1 customer, 30% 2 c., and 50% 3 c.
- Customers who arrive at the pharmacy have 1, 2, or 3 prescriptions with 50%, 30%, and 20% probabilities
- The service time mean is 3, 4, and 5 minutes, respectively
- Statistics to collect are the average number of prescriptions in the system and the average time spent by the customer
- Collecting only the first 30 arrivals



File: Pharmacist_chapter2.doe

Defining Variables and Attributes

- VARIABLES: quantities that are properties of the system that may change
  - Suggestion: its name starts with *v* (for example, *vLambda*)
  - Variables are used to share information across all modules in the model
  - To define a variable is possible through the spreadsheet view or through a dialog box

Variable - Basic Process

	Name	Rows	Columns	Data Type	Clear Option	Initial Values	Report Statistics
1	vScalar			Real	System	0 rows	
2	v1DArray	3		Real	System	3 rows	
3	v2DArray	2	5	Real	System	10 rows	

Double-click here to add a new row.

Initial Values

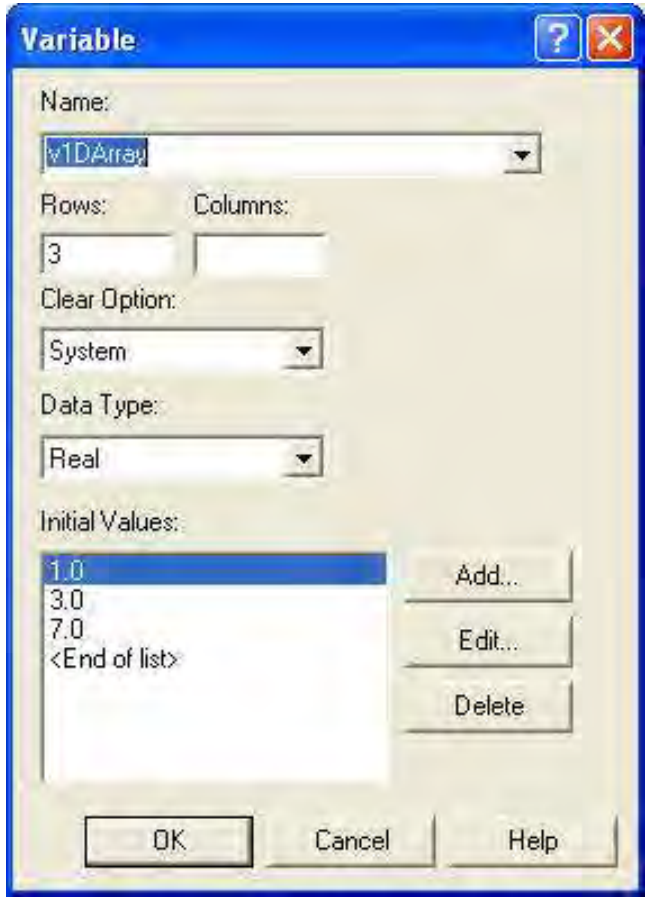
	1	2	3	4	5
1	1.1	1.2	3.1	9.0	99.9
2	10.5	4.3	0.0	2.9	27.4

Variable - Basic Process

	Name	Rows	Columns	Data Type	Clear Option	Initial Values	Report Statistics
1	vScalar			Real	System	0 rows	
2	v1DArray	3		Real	System	3 rows	
3	v2DArray	2	5	Real	System	10 rows	

Double-click here to add a new row.

Click to enter values



Defining Variables and Attributes (cont.)

- ATTRIBUTE: It is a named property or characteristic of an entity
  - Suggestion: its name starts with *my* (for example, *myArrivalTime*)
  - For example: dimensions, color, reference, ...
  - There are predefined attributes that ARENA uses to track entities
    - IDENT: to identify entities (each entity has a different value)
    - Entity.SerialNumber: this number is unique when the entity is created, but it is the same if the entity is cloned
    - Entity.Type: It is useful to distinguish entities after they are created. Also, it is used for the entity picture and cost attributes

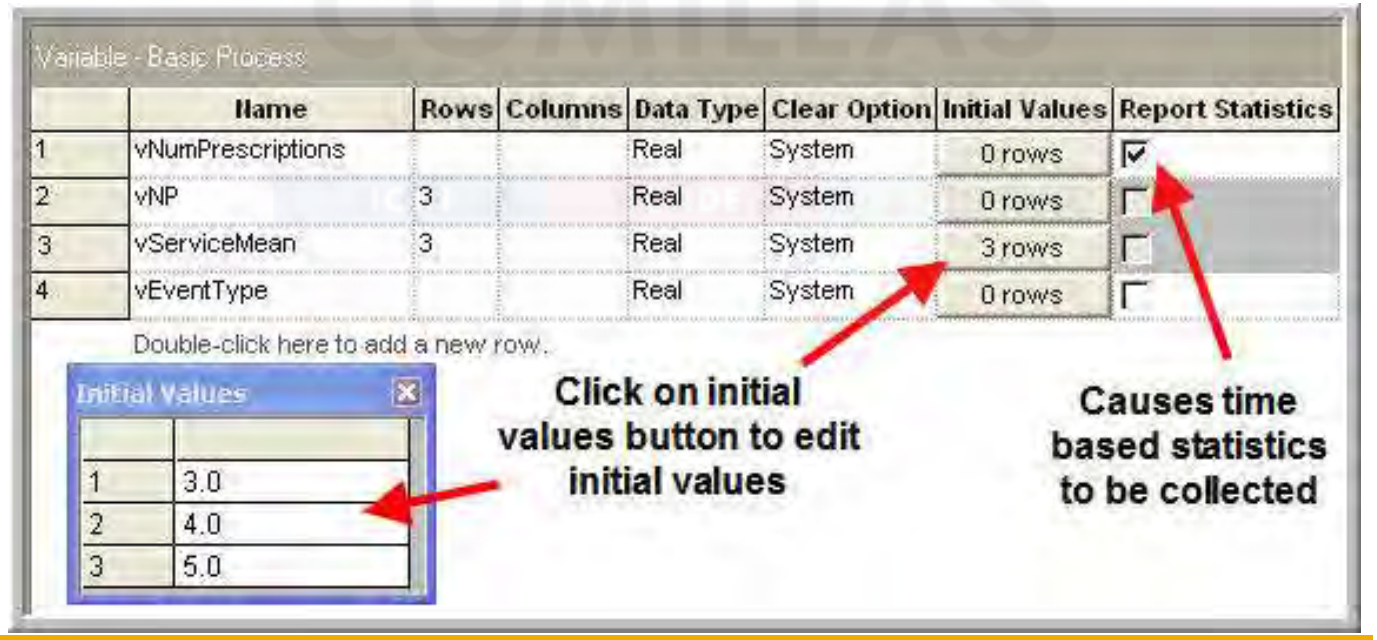
Predefined attributes | User-defined attributes

IDENT	Entity.SerialNumber	Entity. Type	Size	Weight	Processing Time
1	1001	1	2	33	20
2	1002	2	3	22	55
3	1003	2	1	11	44
4	1004	1	2	33	20
5	1005	1	5	10	14
6	1006	3	4	14	10

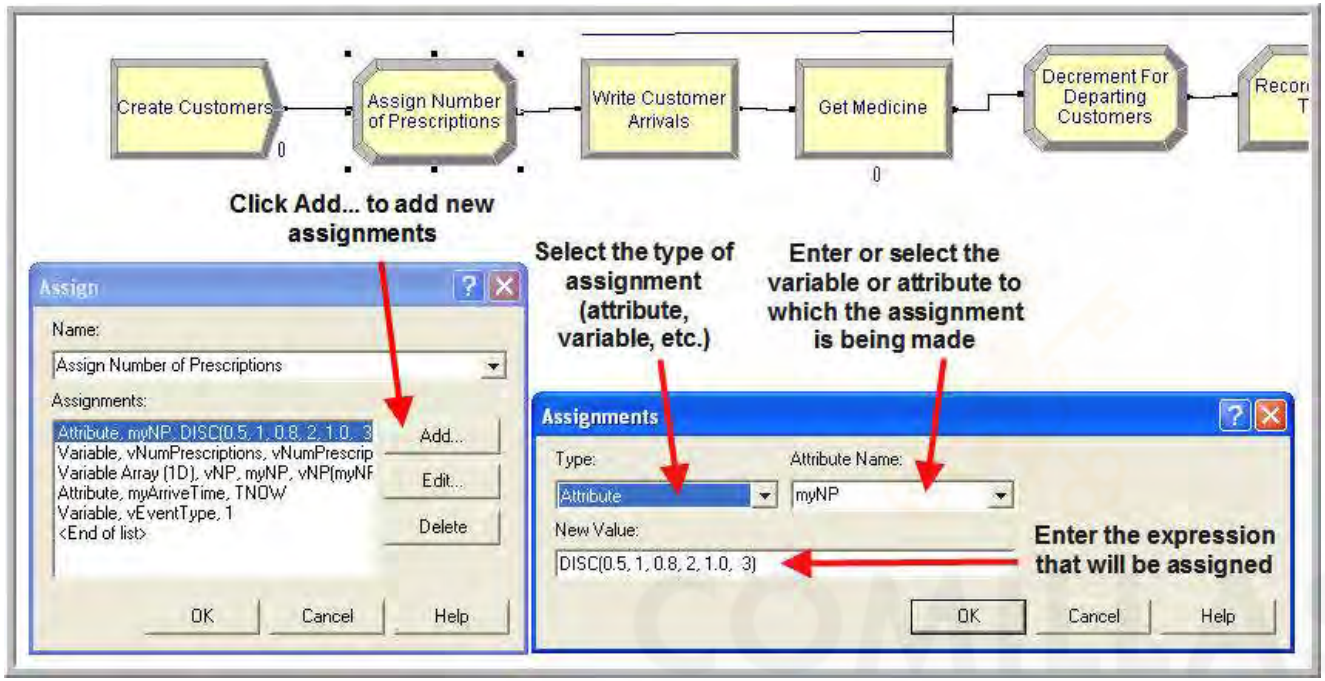
System Performance of the demo model

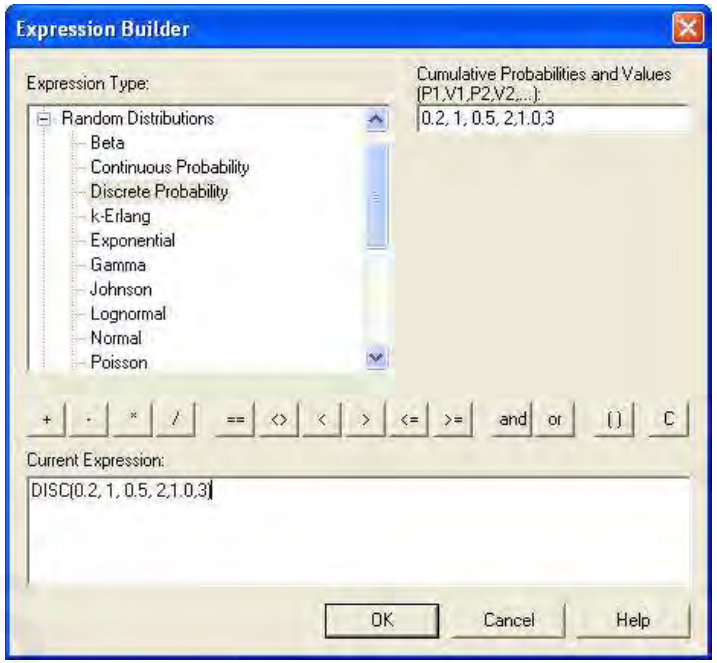
Variables:

- vNumPrescriptions: Scalar variable that counts the total number of prescriptions in the system (initial v.=0)
- vNP: a 1D variable with 3 rows and counts the number of customers having 1, 2, and 3 prescriptions currently in the system
- vServiceMean: a 1D variable with 3 rows representing the mean of the service distributions for the 3 prescription quantities (initial values = 3, 4, and 5)



ASSIGN module (where values of variables/attributes are assigned)

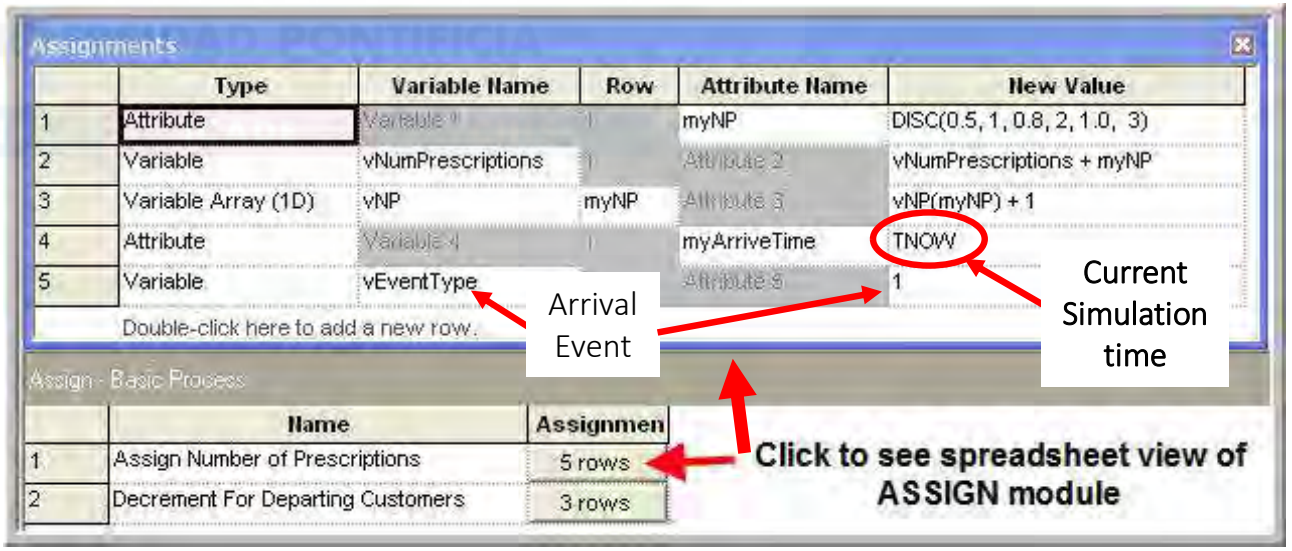




$DISC(cp_1,v_1,cp_2,v_2,\ldots)$
Discrete probability function with probabilities:

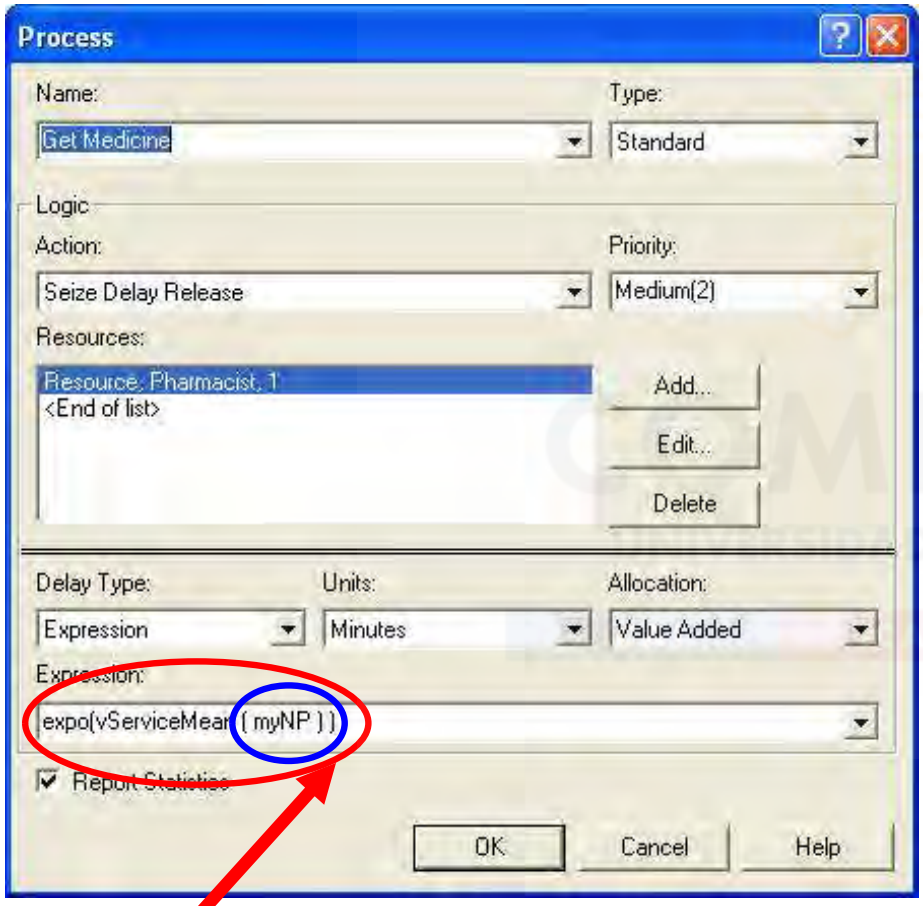
$$P(X = vi) = cpi - cp_{i-1}$$

The order of assignments is very important!

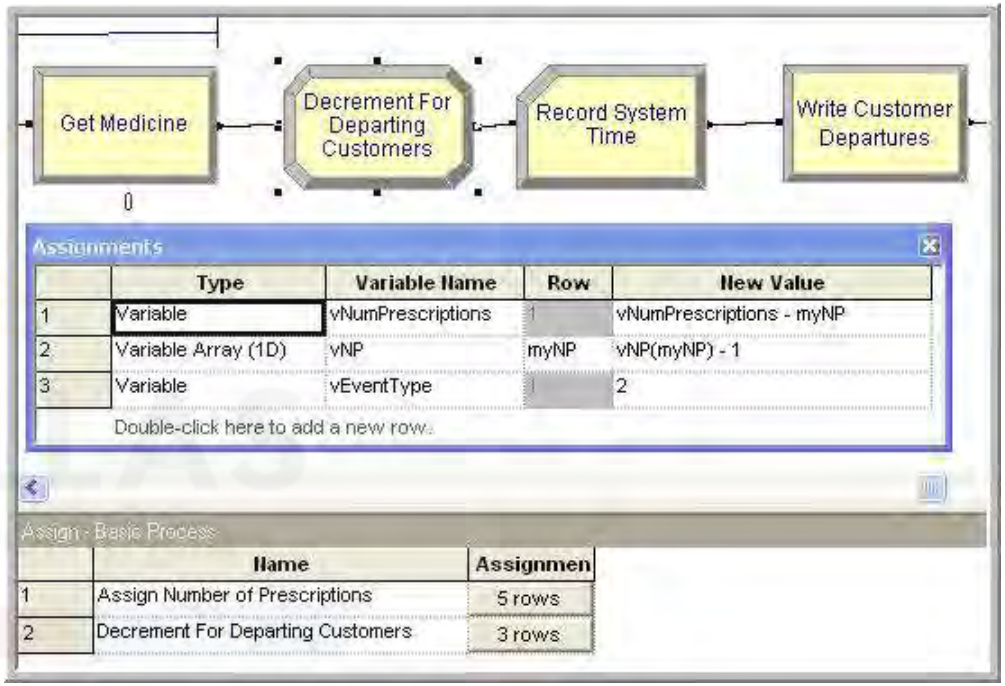


PROCESS module
Updated statistics with ASSIGN

- Including the service time mean dependent on the number of prescriptions



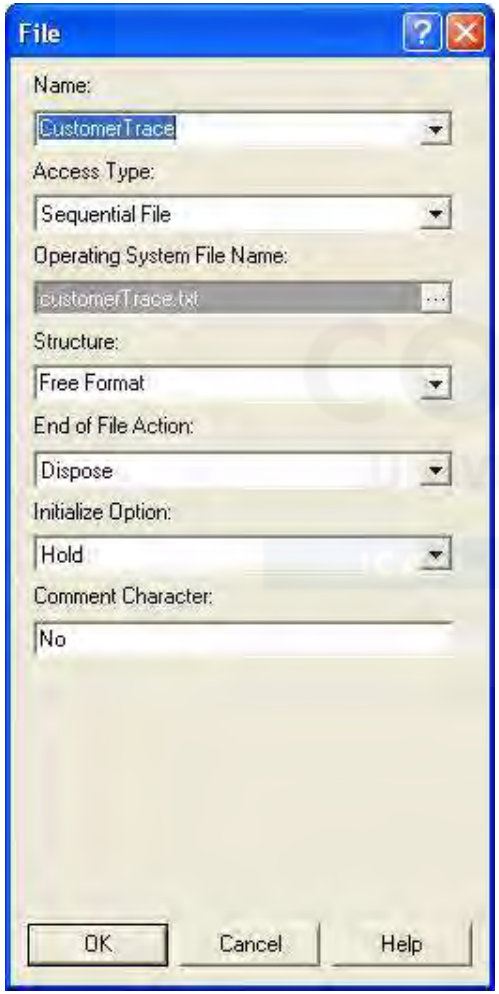
This way to index arrays is very common



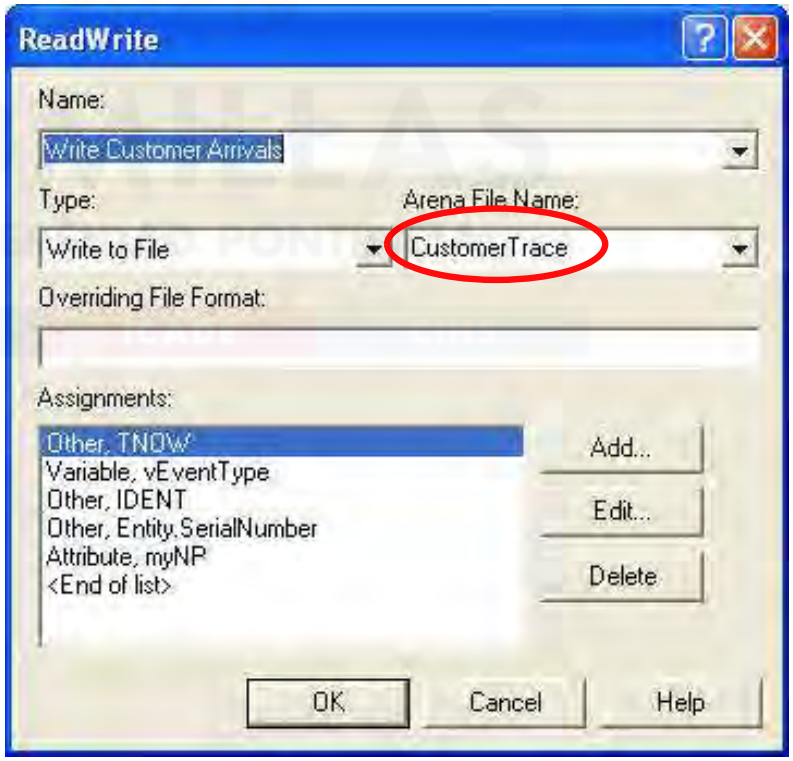
Updated variables:
- *vNumPrescriptions*: Subtracting *myNP*
- *vNP*: Subtracting only one from the *myNP* count
- *vEventType*: Set to 2 as a departure event

READWRITE module (read from/write to a file)

- The READWRITE module helps to debug the model (analyzing arrival and departure times) in the Advanced Process Panel
- First, it is necessary to define a FILE in the Advanced Process Panel



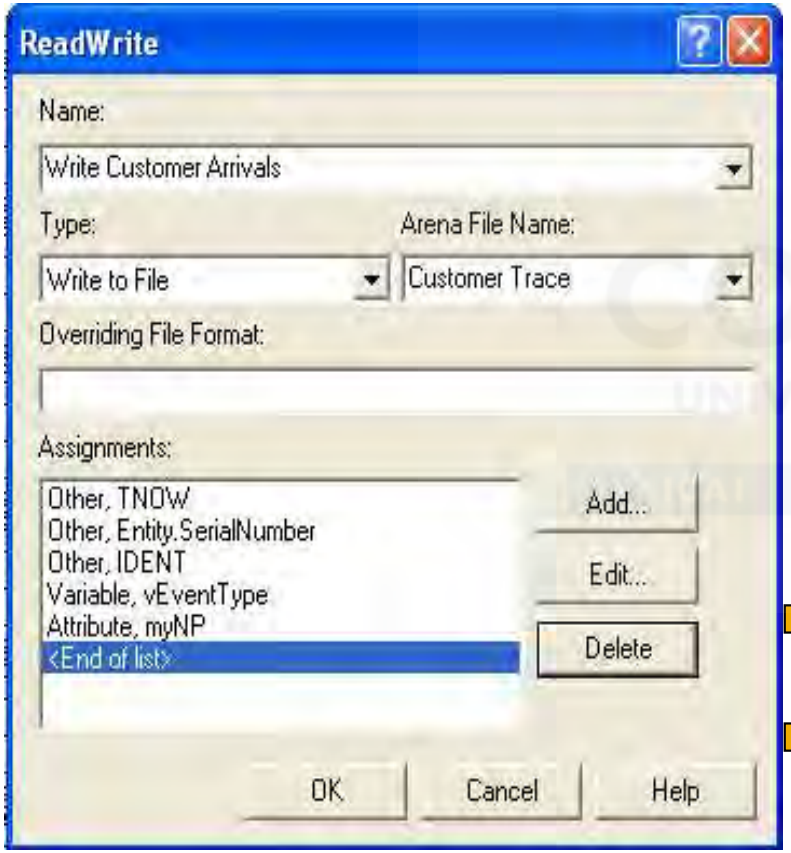
Sequential File: A text file whose records will be in the same sequence as they are written
Free format: each value in the file is separated by a space

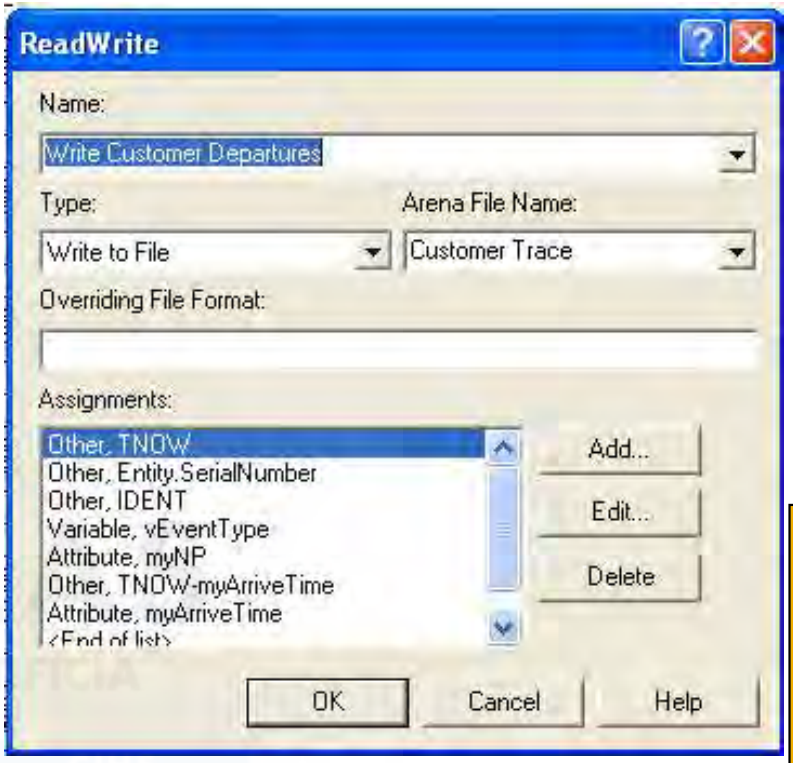


Written Information

TNOW: *Current Simulation Time*
vEventType: *Type of Event*
IDENT: *Entity identity number*
Entity.SerialNumber
myNP: *number of prescriptions for the customer*

READWRITE to FILE



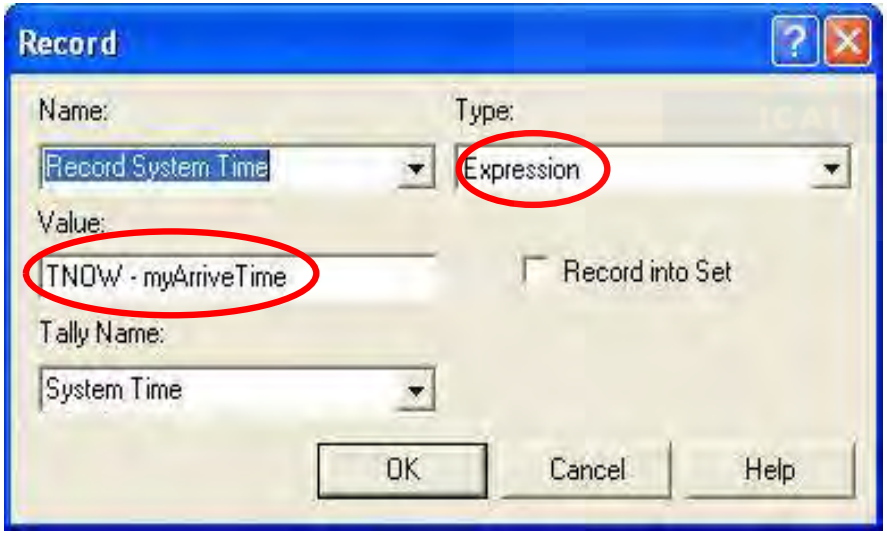


FILE: Customer Trace.txt

2.076914 1.000000 2.000000 1.000000 1.000000
2.076914 2.000000 4.000000 1.000000 1.000000
2.498945 1.000000 2.000000 2.000000 1.000000 0.422032 2.076914
6.400697 3.000000 3.000000 1.000000 3.000000
6.400697 4.000000 6.000000 1.000000 1.000000
6.400697 5.000000 7.000000 1.000000 3.000000
11.064971 2.000000 4.000000 2.000000 1.000000 8.988057 2.076914
26.578563 3.000000 3.000000 2.000000 3.000000 20.177866 6.400697
26.941828 4.000000 6.000000 2.000000 1.000000 20.541131 6.400697
30.096515 5.000000 7.000000 2.000000 3.000000 23.695817 6.400697
37.113203 6.000000 5.000000 1.000000 1.000000

RECORD module

- Module in the Basic Process Panel
- This module "records" information each time an entity passes through it
- It is necessary to compute the average time in the System
- The options included are:
  - *Count*: Increase or decrease the value of the named counter by a specified value (useful to obtain statistics about how many entities flow through the model)
  - *Entity Statistics*: Generate general entity statistics (time and cost/duration information)
  - *Time Interval*: To calculate and record the difference between a specified attribute value and the current simulation time
  - *Time Between*: To track and record the time between entities entering the module
  - *Expression*: To record the value of the specified expression



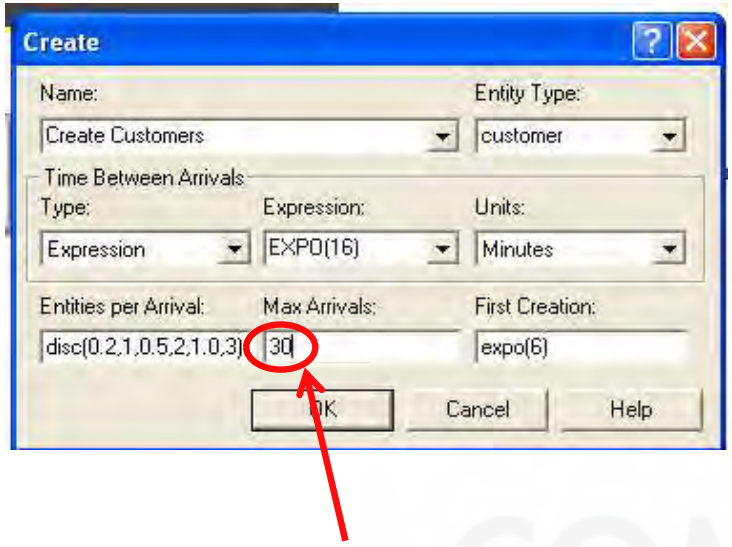
Tally

Expression	Average	Half Width	Minimum Value	Maximum Value
Record System Time	14.8424	0.638379141	0.00002686	157.58

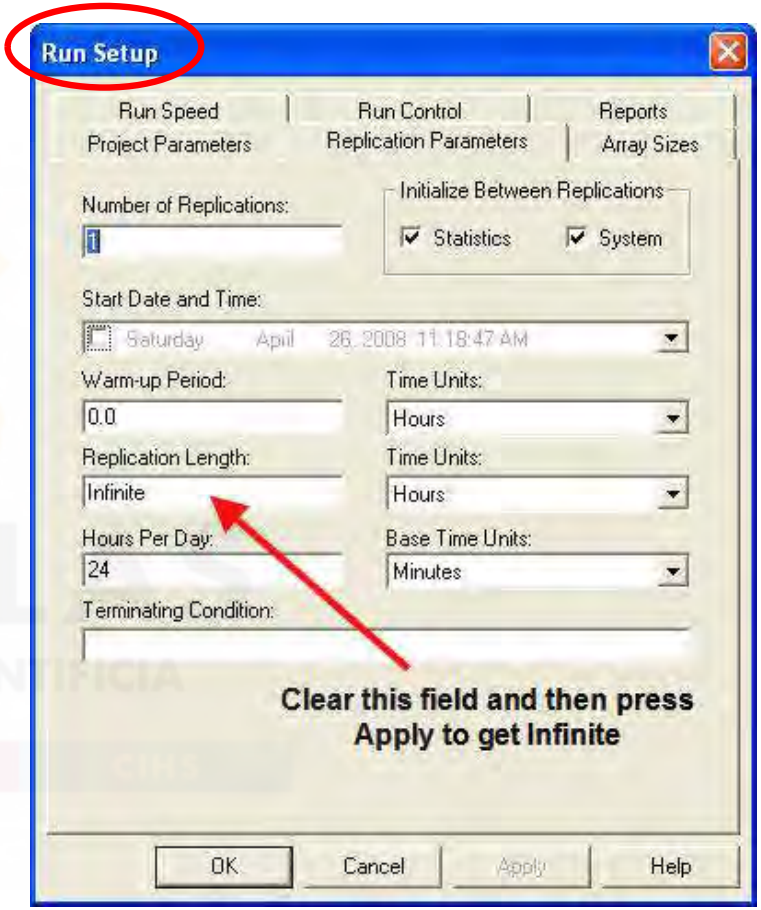
Time Persistent

Variable	Average	Half Width	Minimum Value	Maximum Value
vNumPrescriptions	3.7162	0.155226793	0.00	71.0000

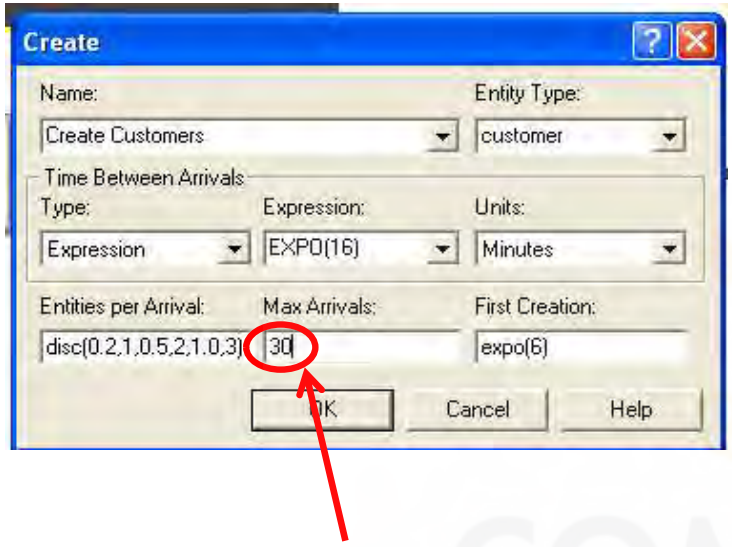
Run the model with 30 first arrivals



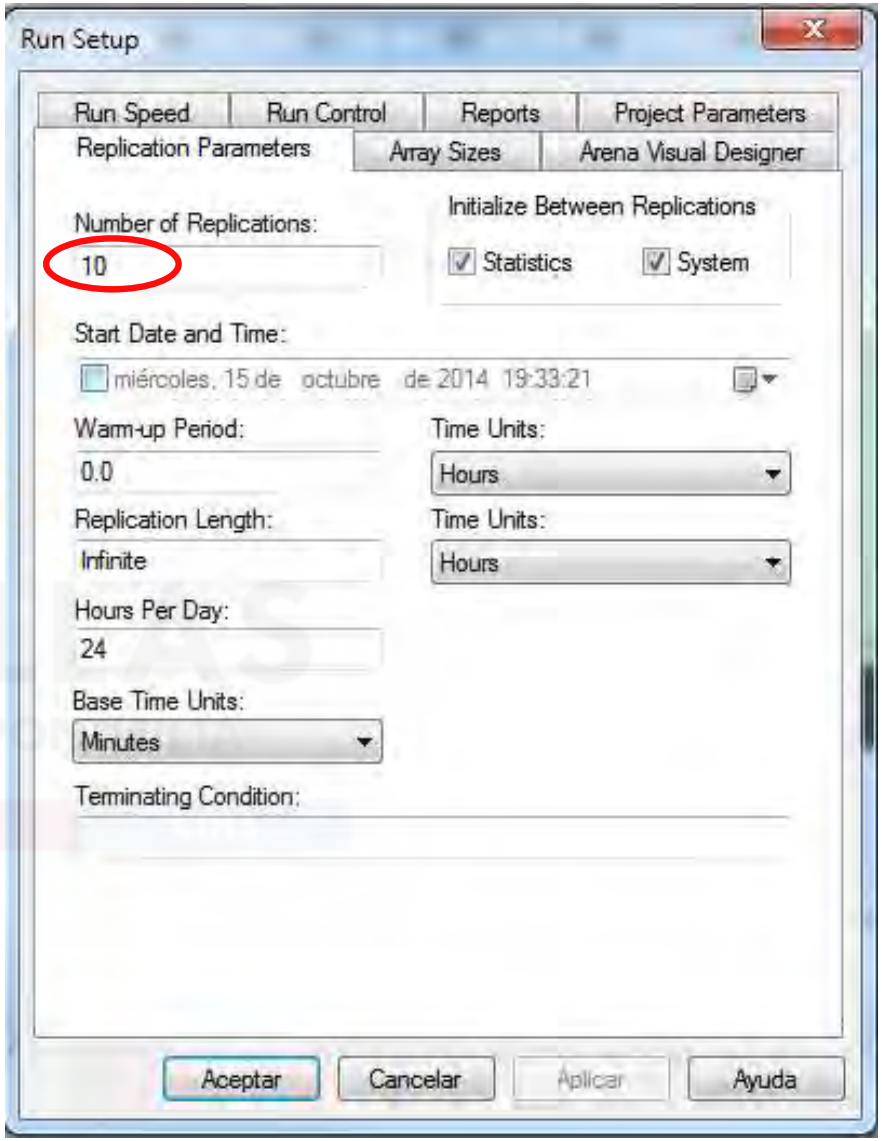
Maximum number of customers



Run the model with 10 replications of 30 first arrivals

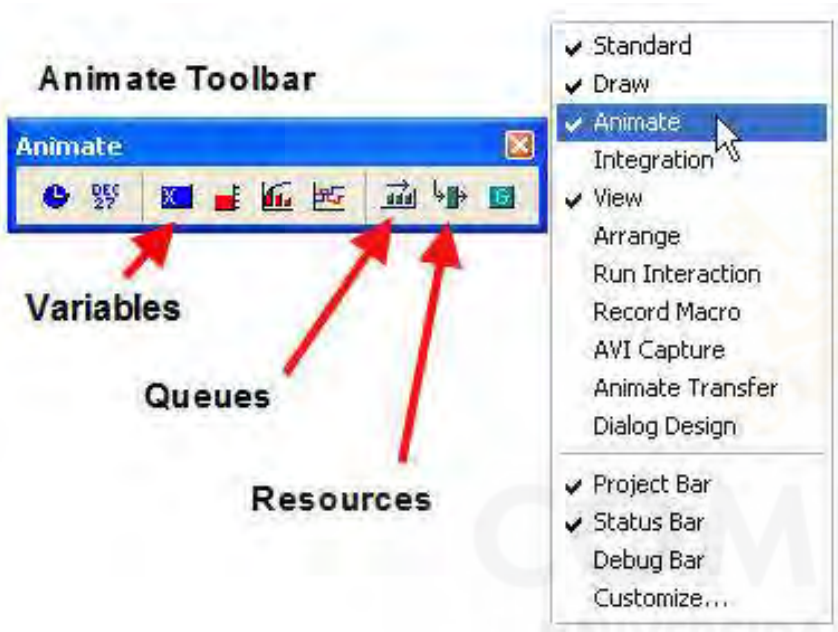


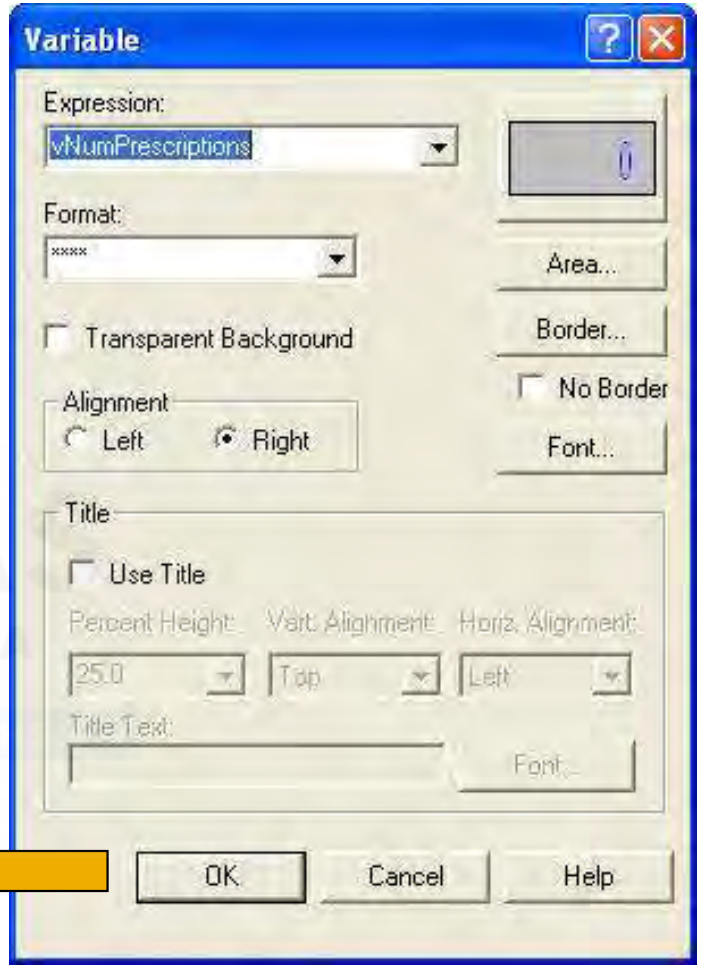
Maximum number of customers

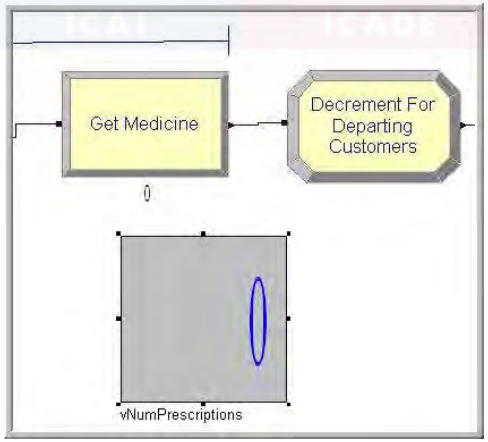


Augment the simulation: Displaying variable values

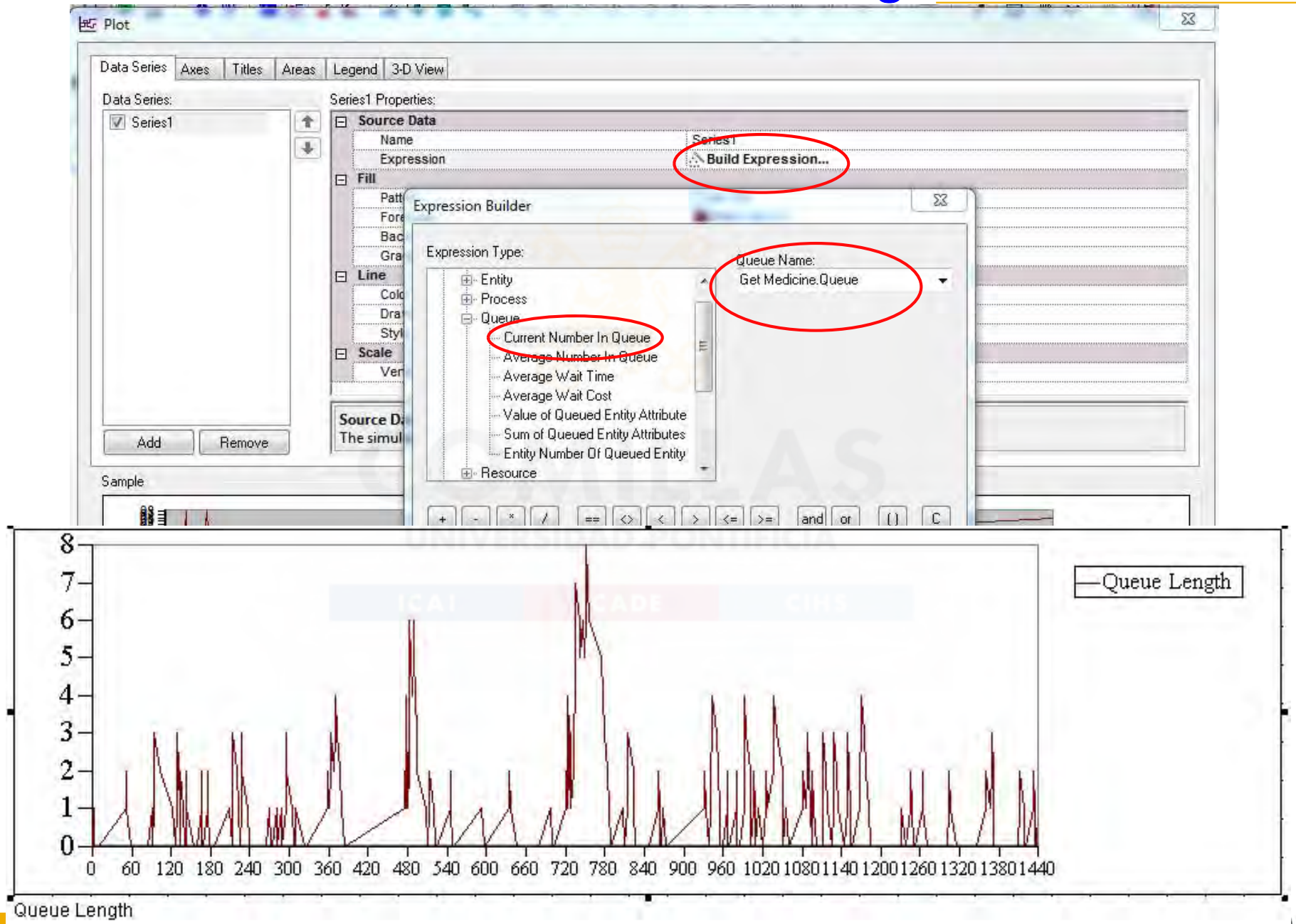
- Display the number of prescriptions in the System (*vNumPrescriptions*)



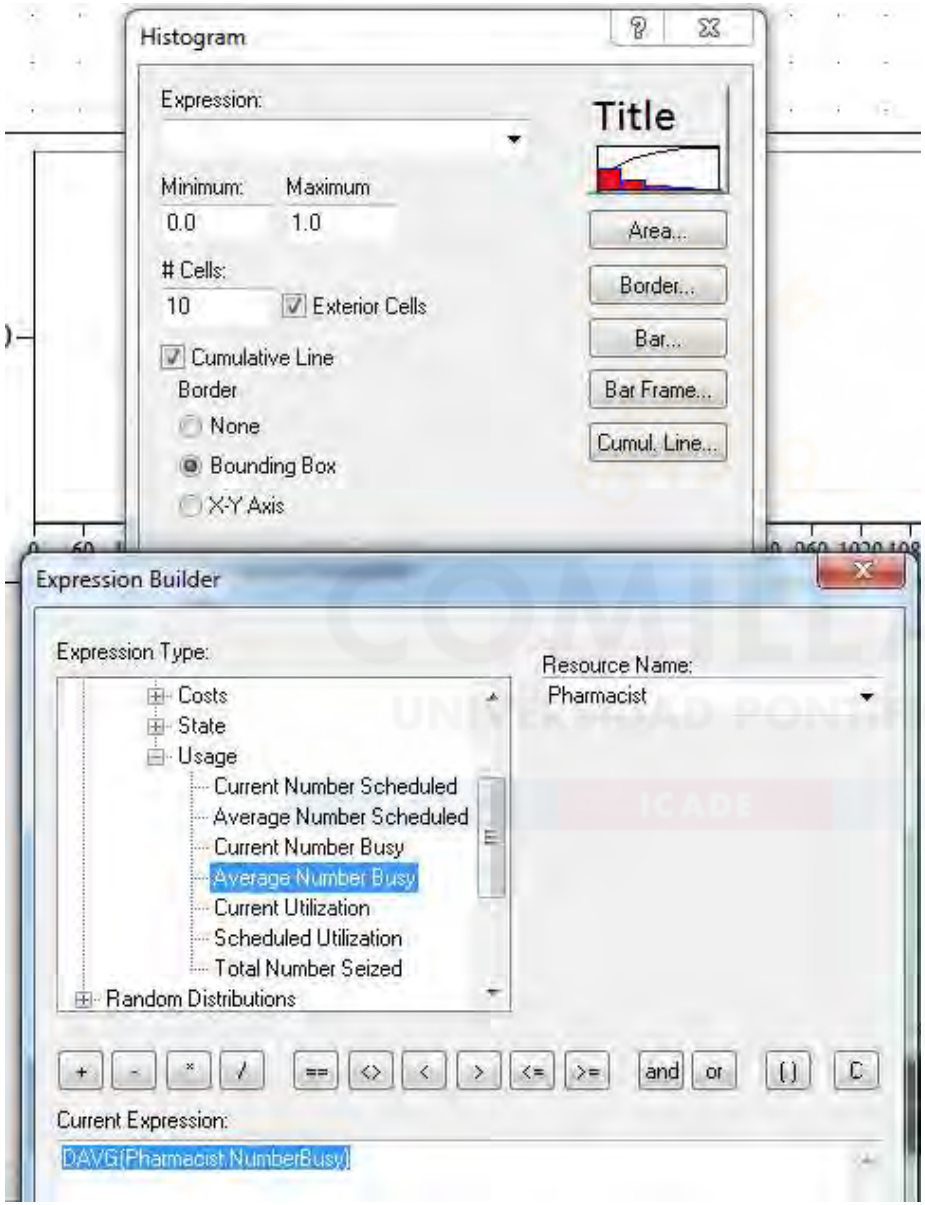


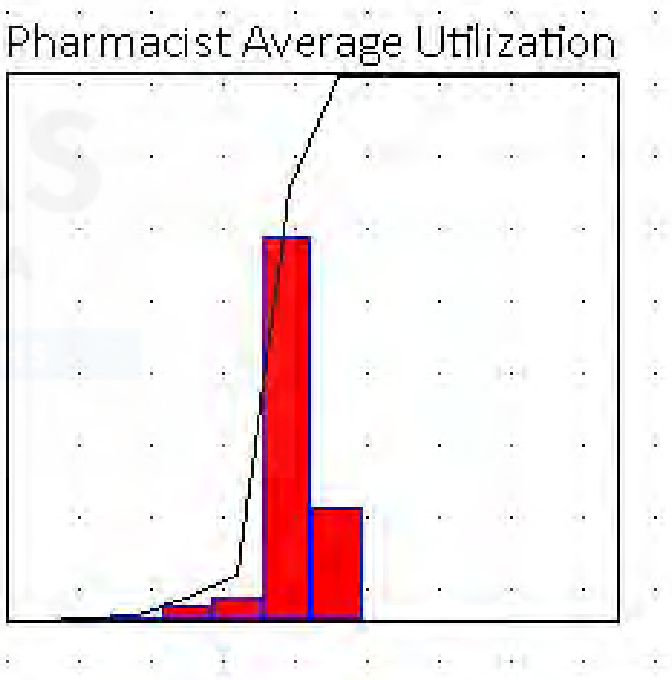


Augment the simulation:
Plot the Current Number in Queue along the Simulation



Augment the simulation:
Plot a histogram of the pharmacist current utilization





ARENA Typical Commands – Distributions/Other commands

Examples of distributions

- Exponential: EXPO(value)
- Triangular: TRIA(minimum, value, maximum)
- Normal: NORM(mean, standard deviation)
- Uniform: UNIF(minimum, maximum)
- DISC: Discrete cumulative distribution function. DISC(cumulative probability 1, value 1, cumulative prob.1, value 2, …, c.p.N, value N).

Other useful stuff

- TNOW: Current simulation time. TNOW records the simulation clock time as the model progresses.
- TFIN: Final simulation time. TFIN is the ending time scheduled for the replication; it is a real-valued quantity.

Commands for resources

- MR(Resource ID):Resource capacity.
- MR returns the capacity units currently defined for the specified Resource ID.
- NR(Resource ID): Number of busy resource units.
- ResUtil(Resource ID): Resource utilization. ResUtil returns the instantaneous utilization of a resource as a real number between 0 and 1, inclusive.

Check out the ARENA Variables Guide

https://cours.etsmtl.ca/gpa662/documents/Cours/Arena%20Variables%20Guide.pdf

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