Practical No. 8

Question-8:
Verify and Validate a Model

Verifying and Validating a Model

Aim:
The aim of this practical is to verify and validate a model of an airport queuing system. The model simulates the operations of an airport, including customer arrivals, queueing at service points, and service times. By running the model and analysing its behaviour, we aim to ensure that the model accurately represents the real-world airport operations.

Introduction:
Efficient airport operations are crucial for ensuring smooth and timely travel experiences for passengers. Agent-based modelling provides a powerful framework for simulating complex systems such as airport operations. In this practical, we develop an agent-based model using AnyLogic software to simulate airport operations, including customer arrivals, queueing, and service times. The model allows us to analyse the efficiency of airport operations and identify potential areas for improvement.

Procedure:

Phase 1: Creating a Simple Model

Create a new model:
Open AnyLogic and create a new project.
Add Process Modelling Library blocks to the diagram:
Add Source, Queue, and Delay blocks from the Process Modelling Library.
Connect them as follows: Source -> Queue -> Delay.
Configure the source block:
Set the arrival rate to 0.3 customers per minute.
Modify the properties of the queue:
Set the queue capacity to 15 agents.
Modify the properties of the delay:
Rename the delay block to "ATM".
Specify the processing time for the ATM.
Run the Model.

Phase 2: Creating Model Animation

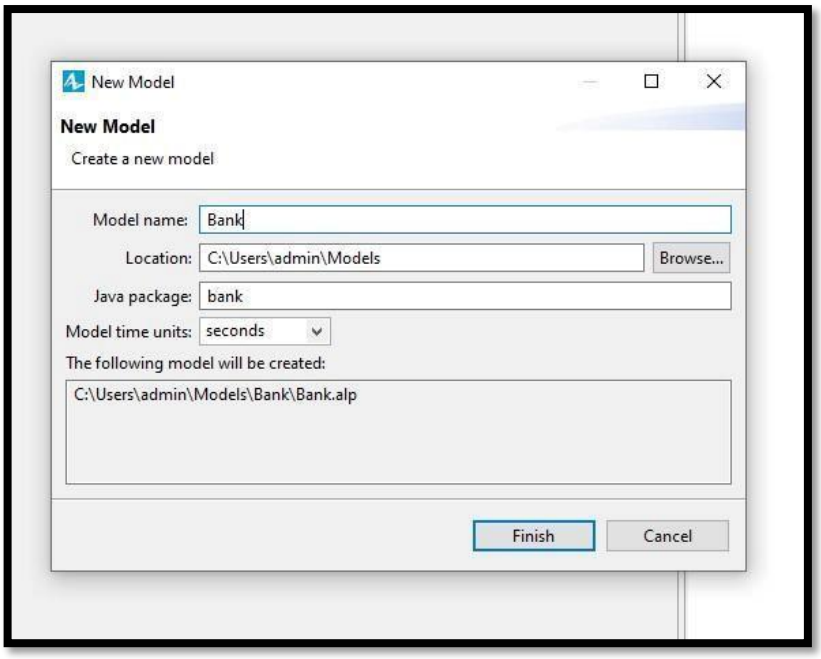
Draw the ATM as a point node.
Set the colour of the ATM shape based on the queue size.
Draw the queue as a path.
Set the agent location for the queue.
Add a 3D Window element to observe the model in 3D.
Create a new agent type named "Customer" and specify it for the source block.
Add an ATM 3D figure to the model.
Run the Model.

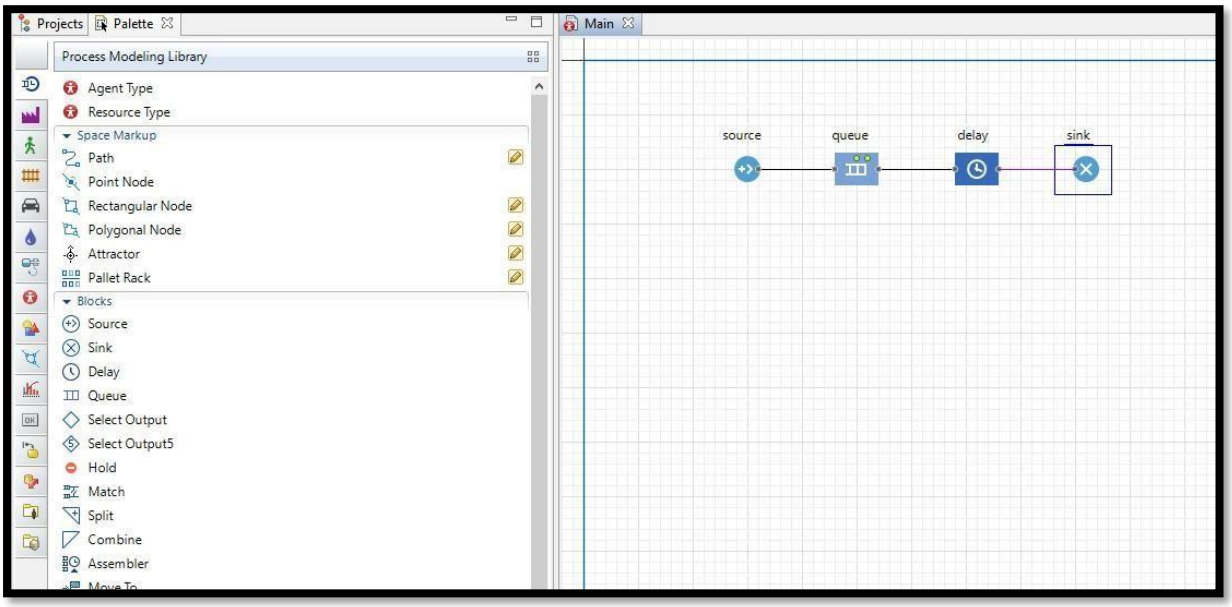
Phase 3: Adding Tellers

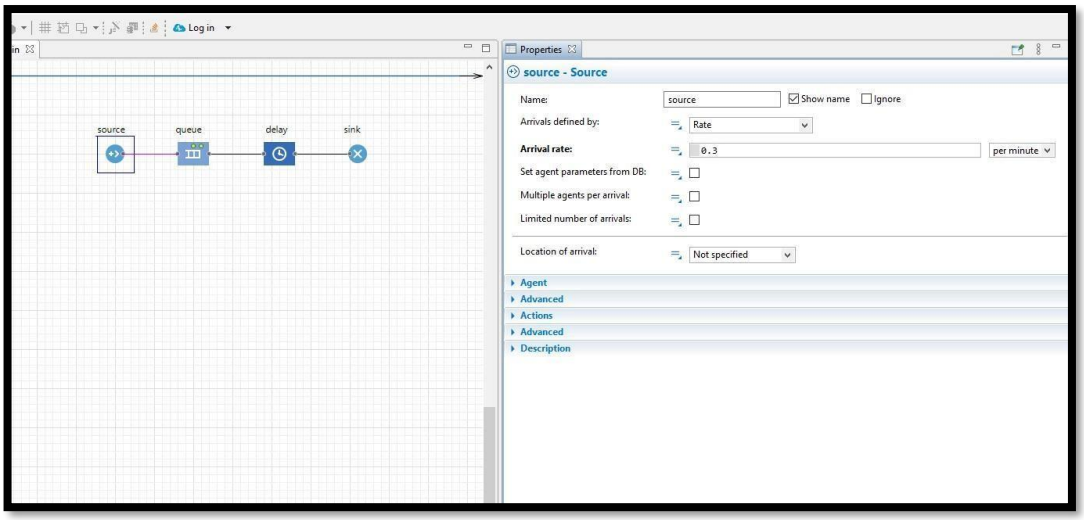
Add Service, SelectOutput, and ResourcePool blocks to the diagram.
Modify the properties of the service block:
Set the queue capacity and service time distribution.
Specify resource allocation for the service.
Add space markup shapes for customers and tellers.
Set up teller locations.
Create a new resource type named "Teller" and specify it for the teller's block.
Add 3D figures for teller stations.
Run the Model.

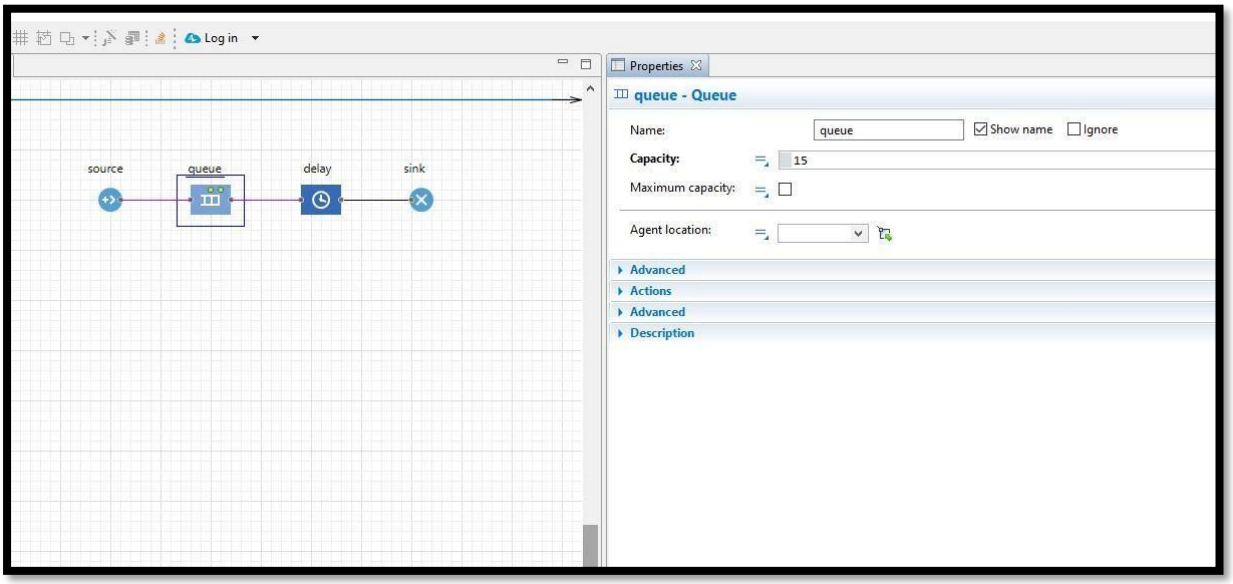
Phase 4: Adding Statistics Collection

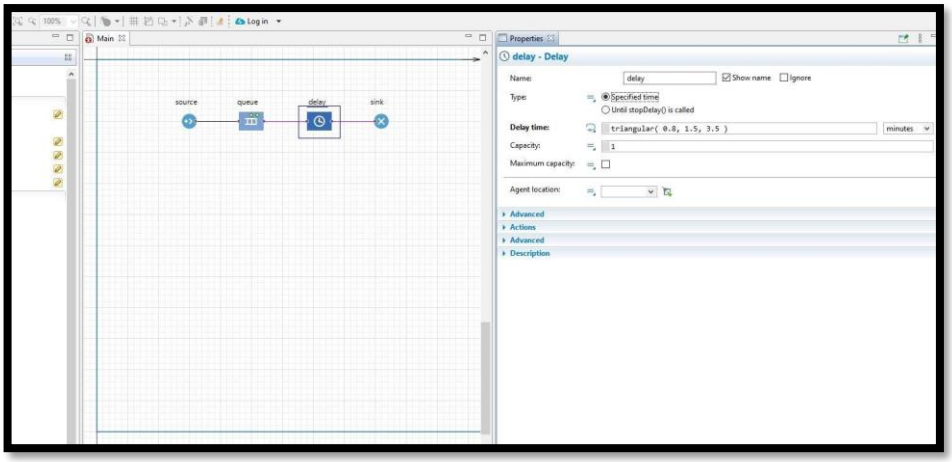
Add bar charts to indicate mean ATM utilization and mean queue length.
Add parameters and histogram data objects to collect time statistics.
Modify source, queue, and sink properties to collect time statistics.
Add histograms to display distributions of customer waiting time and time in the system.
Run the Model.

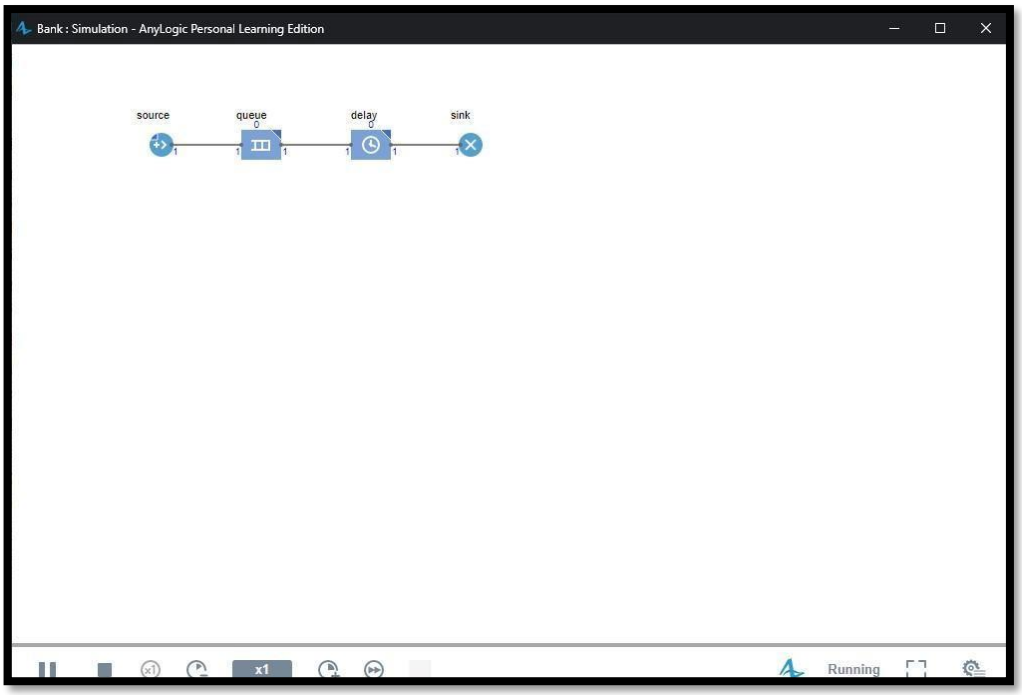

New Model
New Model
Create a new model
Model name: Bank
Location: C:\Users\admin\Models
Browse...
Java package: bank
Model time units: seconds
The following model will be created:
C:\Users\admin\Models\Bank\Bank.alp
Finish
Cancel


Projects
Palette
Process Modeling Library
Agent Type
Resource Type
Space Markup
Path
Point Node
Rectangular Node
Polygonal Node
Attractor
Pallet Rack
Blocks
Source
Sink
Delay
Queue
Select Output
Select Output5
Hold
Match
Split
Combine
Assembler
Main
source
queue
delay
sink

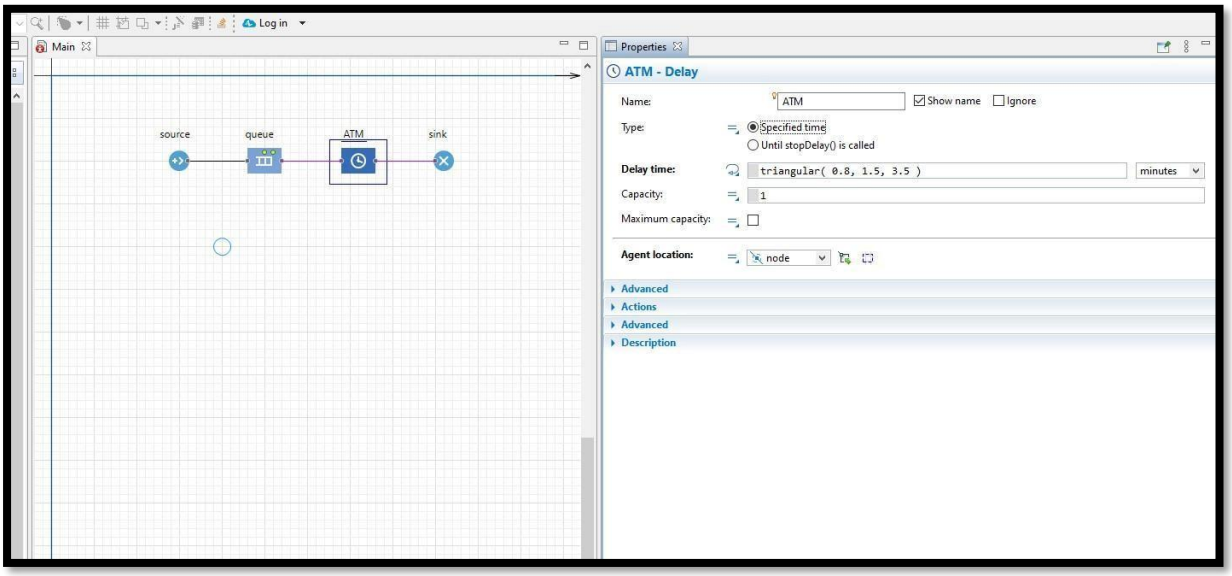

Log in
source
queue
delay
sink
Properties
source - Source
Name:
source
Show name
Ignore
Arrivals defined by:
Rate
Arrival rate:
0.3
per minute
Set agent parameters from DB:
Multiple agents per arrival:
Limited number of arrivals:
Location of arrival:
Not specified
Agent
Advanced
Actions
Advanced
Description

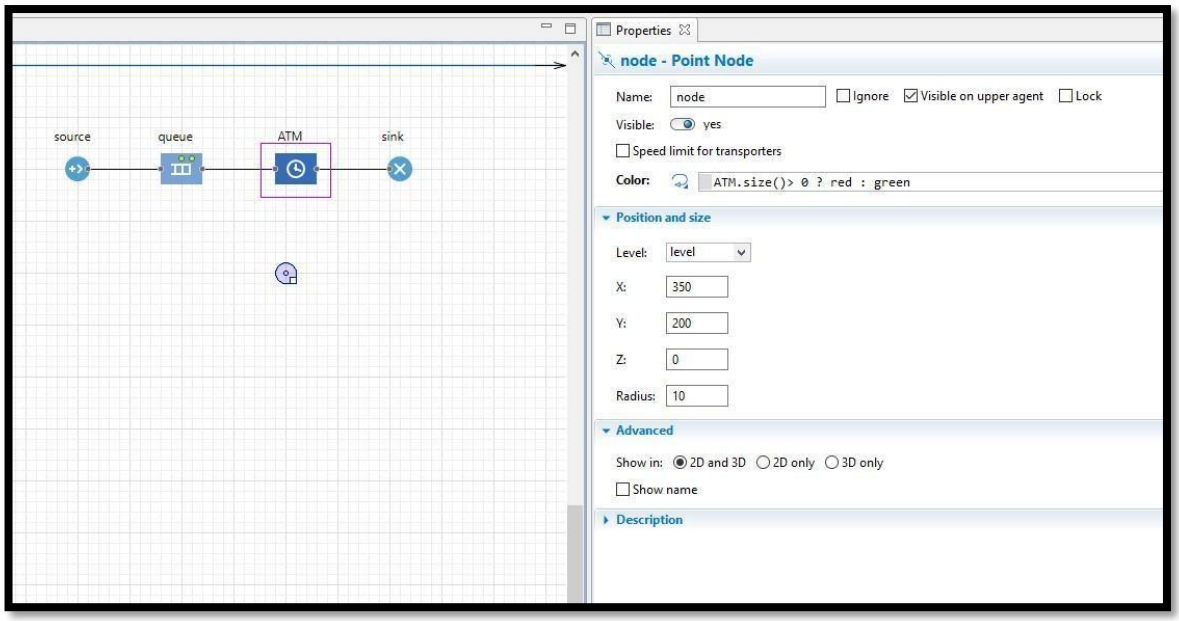

Log in
source
queue
delay
sink
Properties
queue - Queue
Name:
queue
Show name
Ignore
Capacity:
15
Maximum capacity:
Agent location:
Advanced
Actions
Advanced
Description

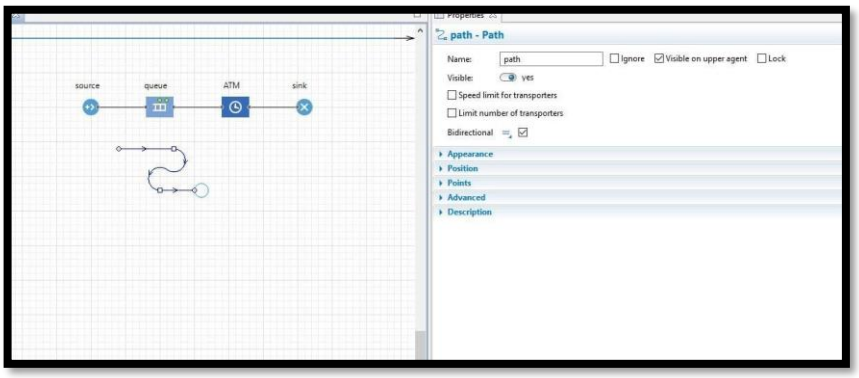

Log in
Main
source
queue
delay
sink
Properties
delay - Delay
Name:
delay
Show name
Ignore
Type:
Specified time
Until stopDelay() is called
Delay time:
triangular(0.8, 1.5, 3.5)
minutes
Capacity:
1
Maximum capacity:
Agent location:
Advanced
Actions
Advanced
Description

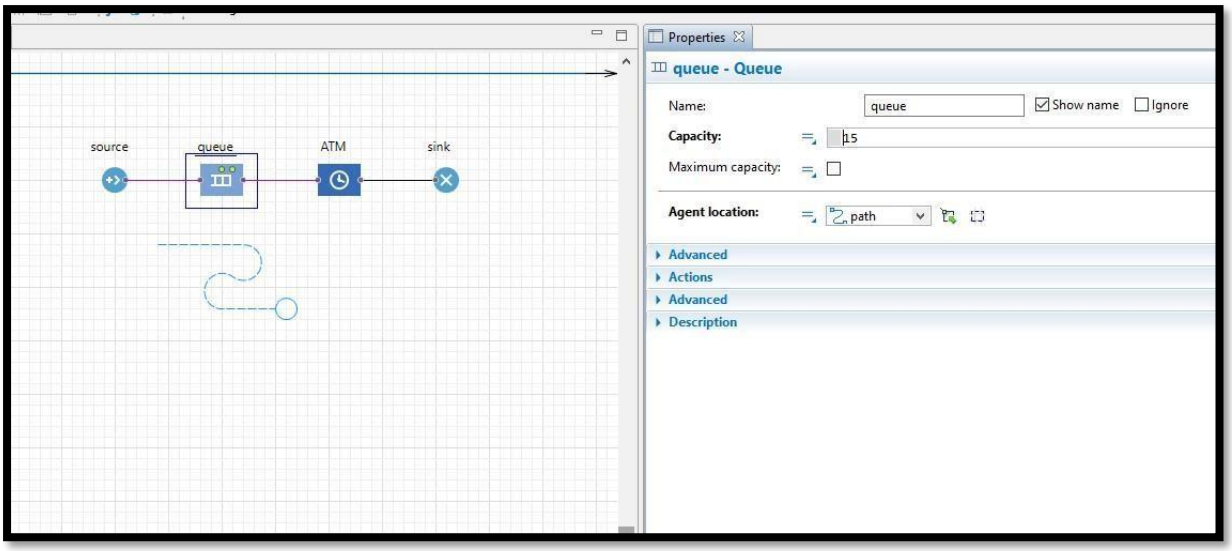

Bank : Simulation - AnyLogic Personal Learning Edition
source
queue
delay
sink
x1
Running

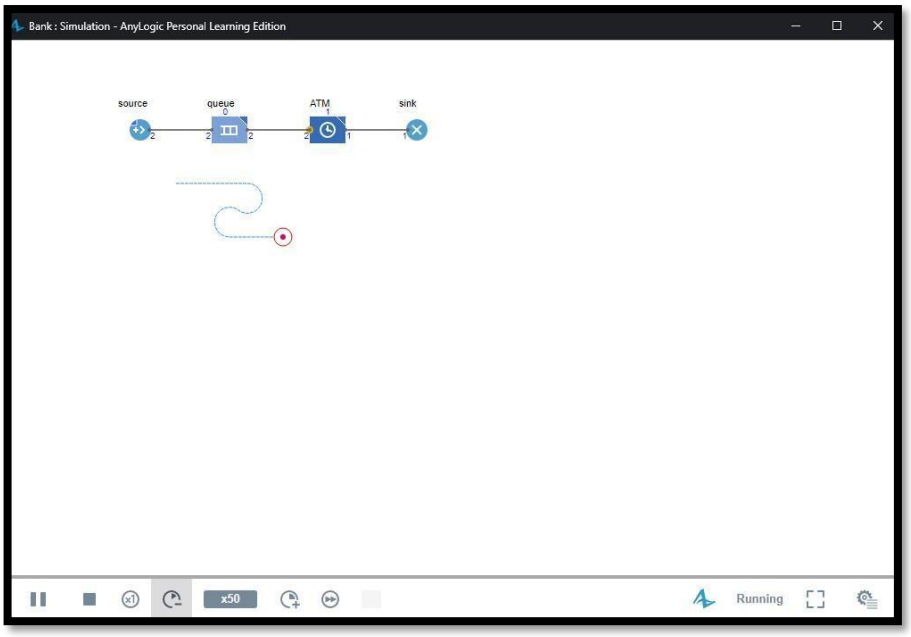
.

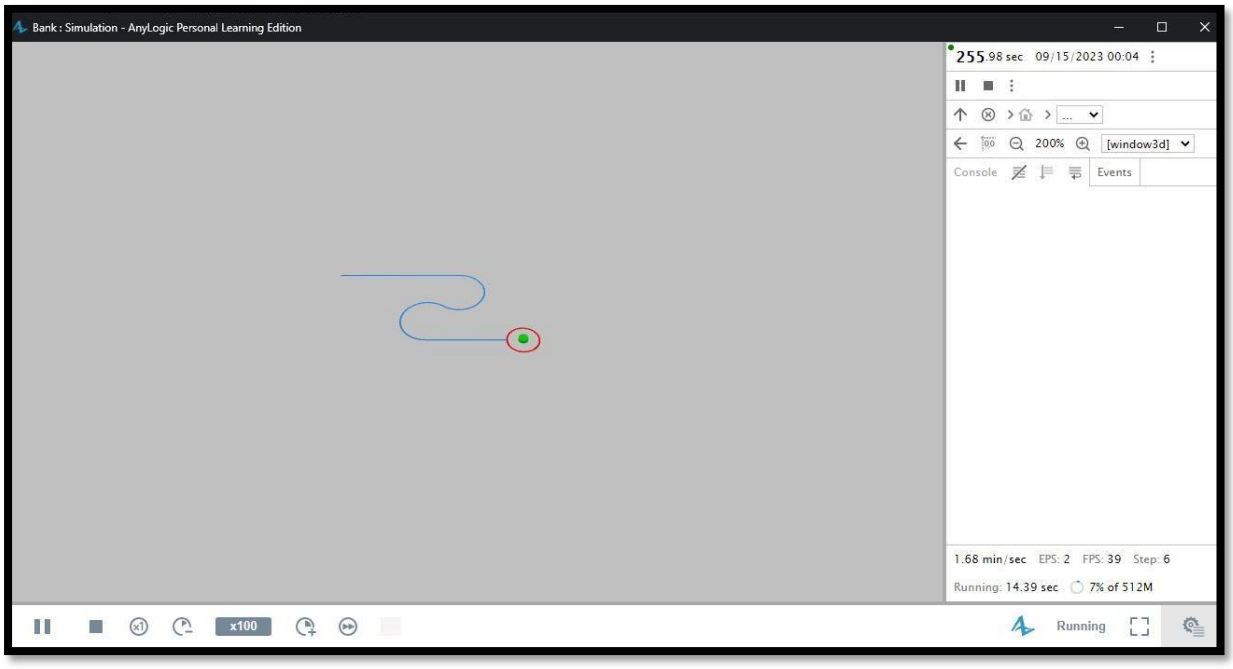

Log in
Main
source
queue
ATM
sink
Properties
ATM - Delay
Name:
ATM
Show name
Ignore
Type:
Specified time
Until stopDelay() is called
Delay time:
triangular(0.8, 1.5, 3.5)
minutes
Capacity:
1
Maximum capacity:
Agent location:
node
Advanced
Actions
Advanced
Description

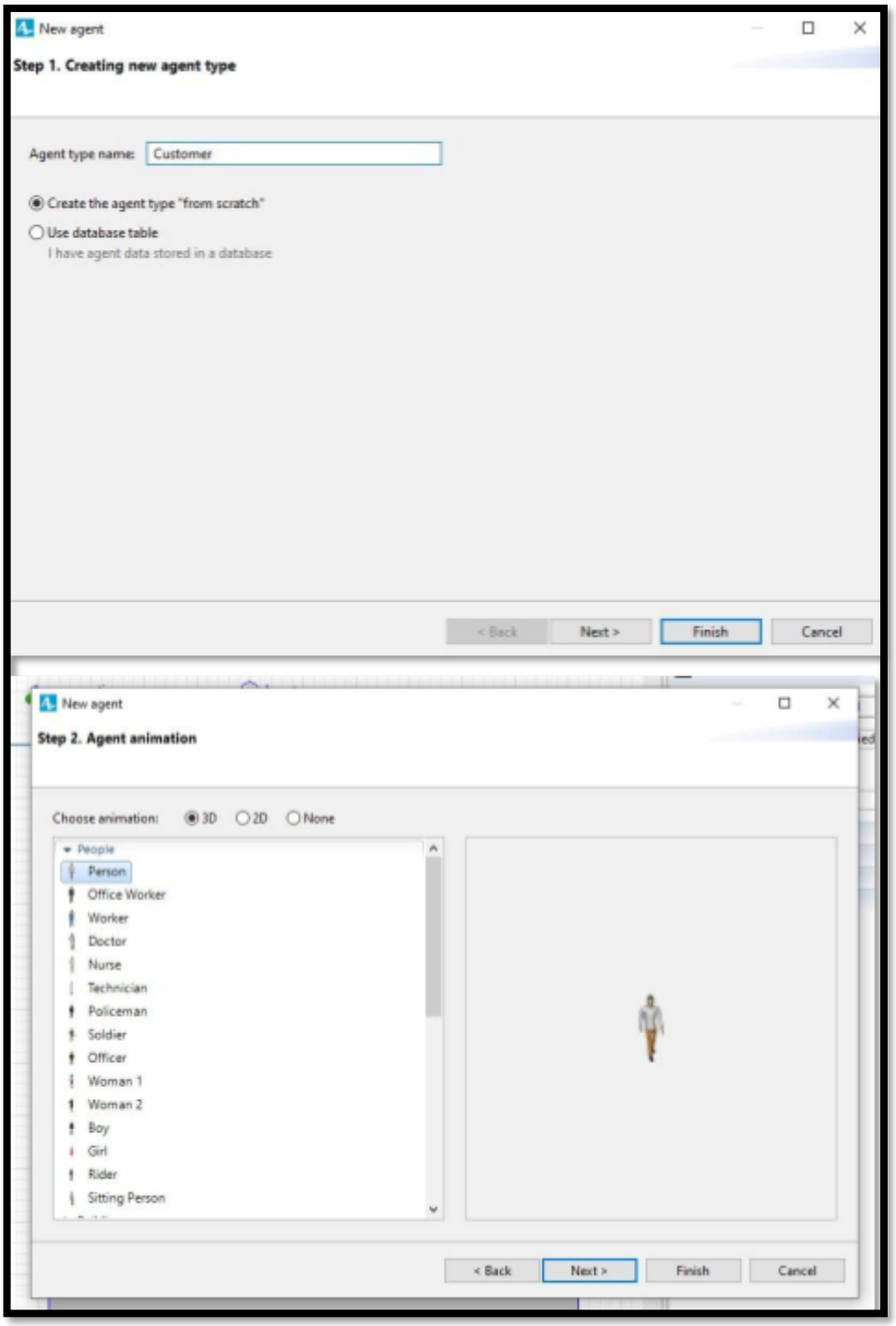

source
queue
ATM
sink
Properties
node - Point Node
Name: node
Ignore
Visible on upper agent
Lock
Visible: yes
Speed limit for transporters
Color: ATM.size()> 0 ? red : green
Position and size
Level: level
X: 350
Y: 200
Z: 0
Radius: 10
Advanced
Show in: 2D and 3D 2D only 3D only
Show name
Description

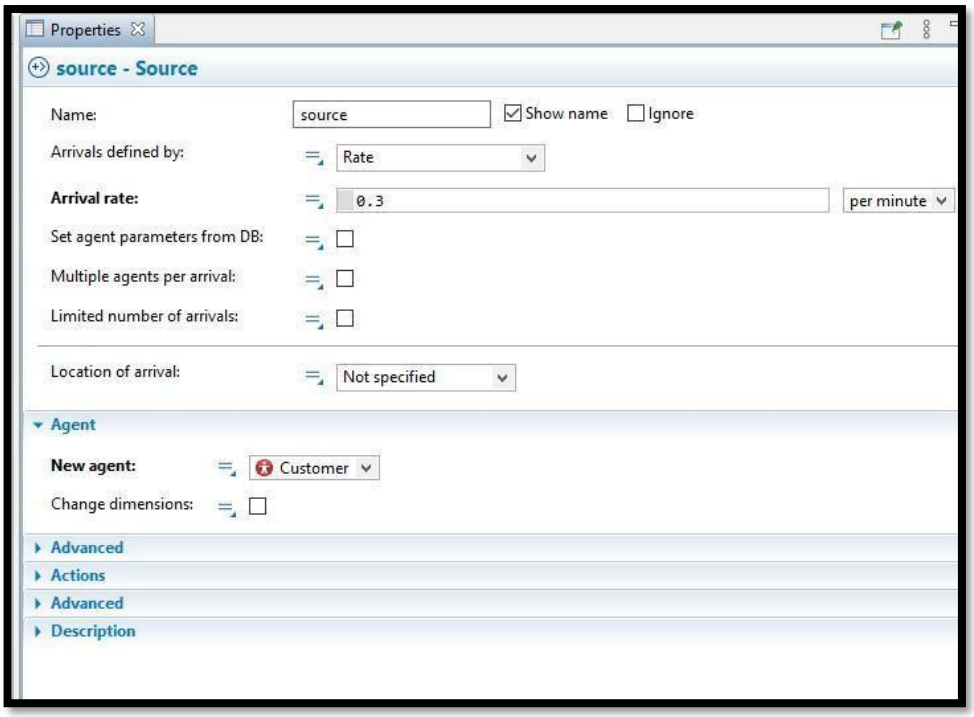

source
queue
ATM
sink
path - Path
Name: path
Ignore
Visible on upper agent
Lock
Visible: yes
Speed limit for transporters
Limit number of transporters
Bidirectional
Appearance
Position
Points
Advanced
Description

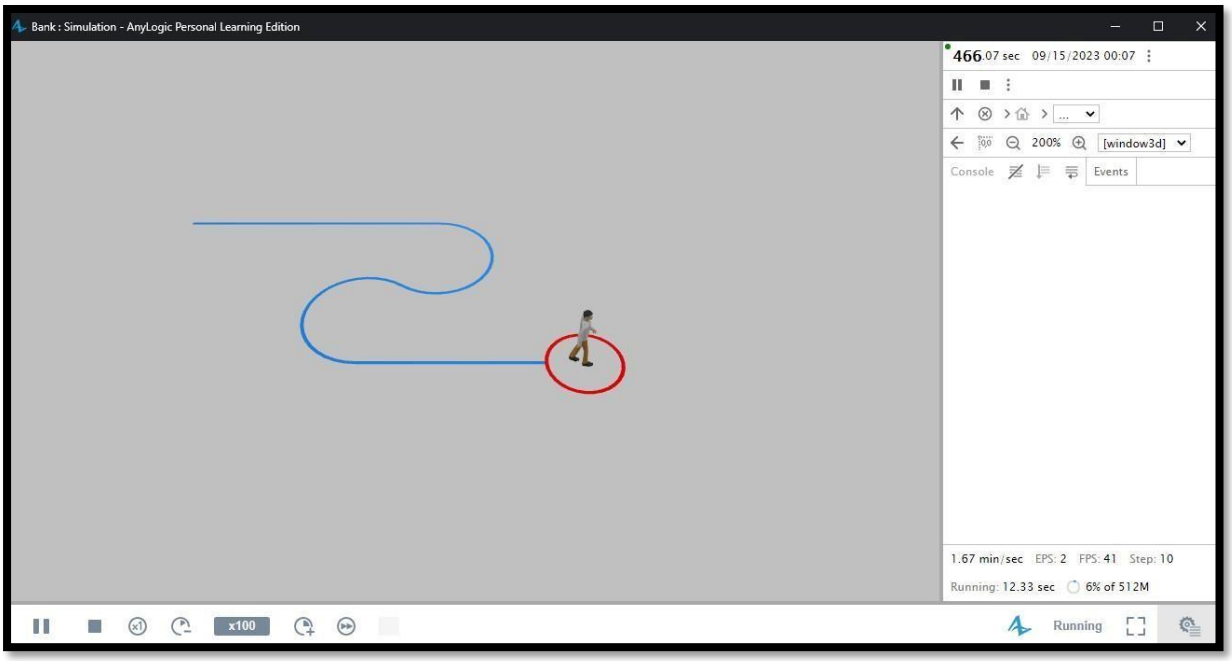

source
queue
ATM
sink
Properties
queue - Queue
Name: queue
Show name
Ignore
Capacity: 15
Maximum capacity:
Agent location: path
Advanced
Actions
Advanced
Description

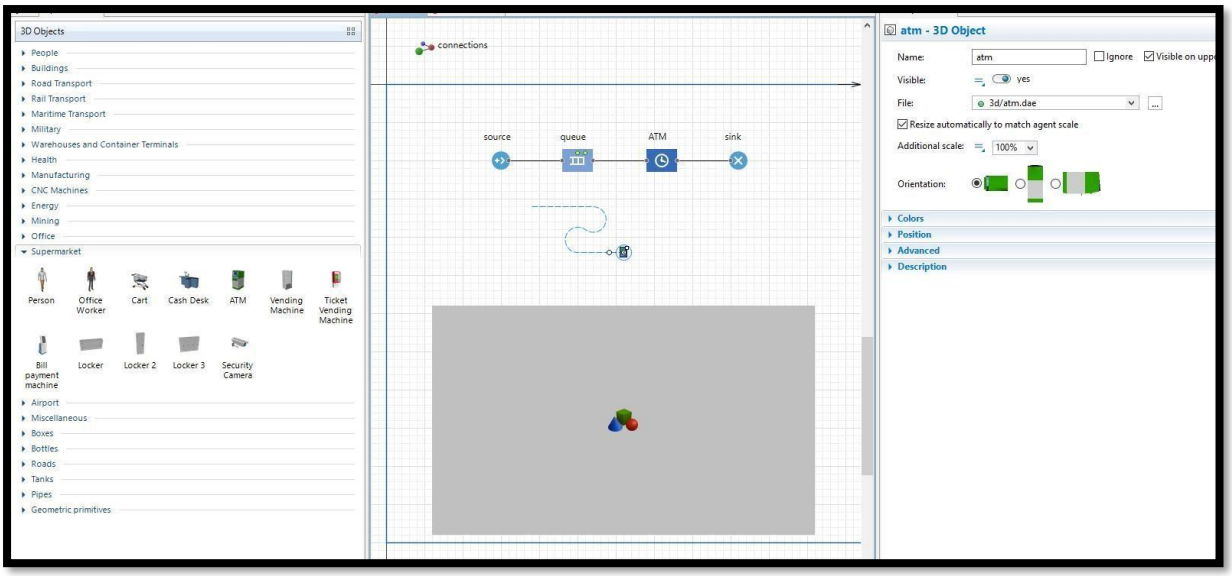

Bank : Simulation - AnyLogic Personal Learning Edition
source
queue
ATM
sink
x50
Running

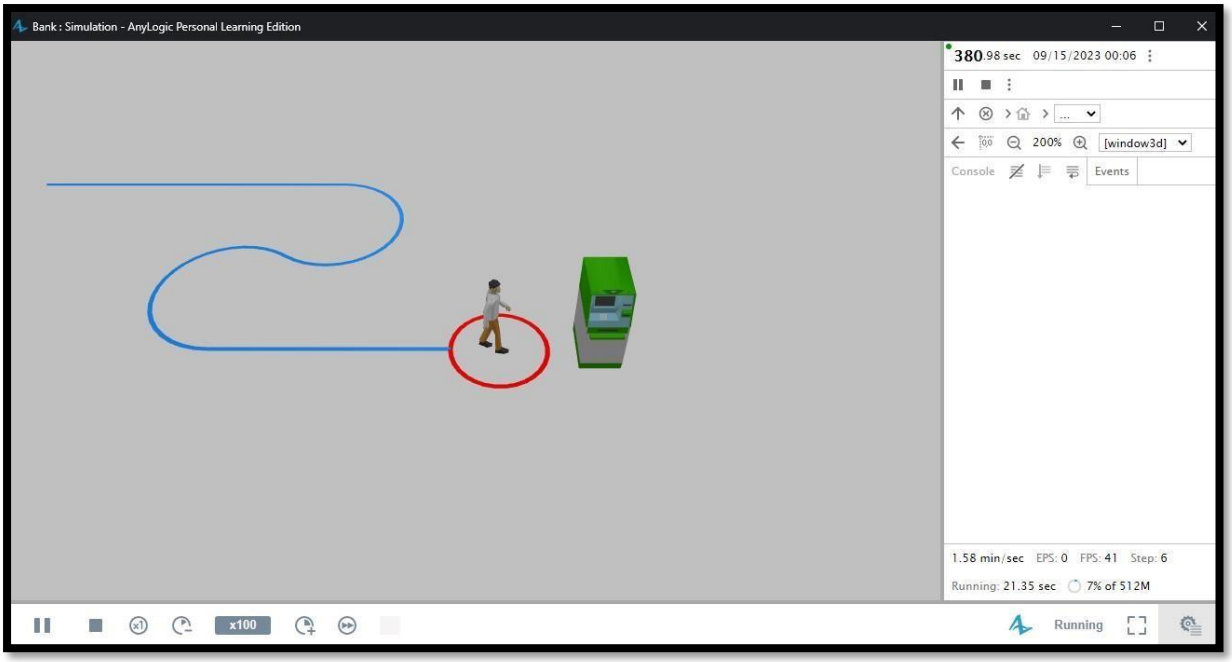

Bank : Simulation - AnyLogic Personal Learning Edition
255.98 sec 09/15/2023 00:04
200%
[window3d]
Console
Events
1.68 min/sec EPS: 2 FPS: 39 Step: 6
Running: 14.39 sec 7% of 512M
x100
Running

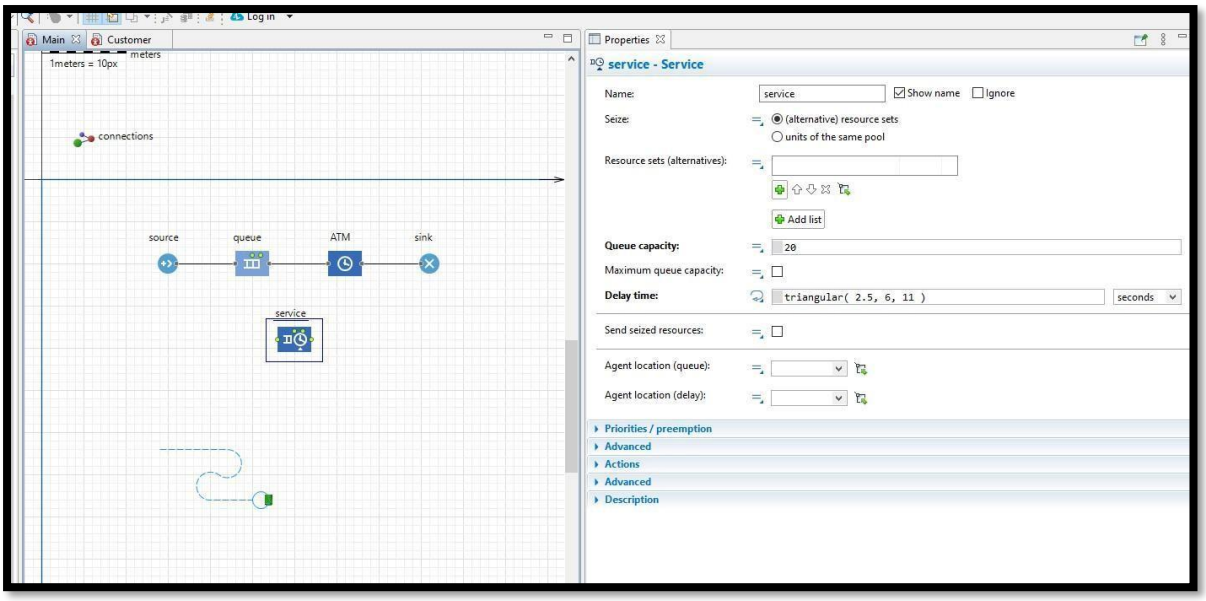

New agent
Step 1. Creating new agent type
Agent type name:
Customer
Create the agent type "from scratch"
Use database table
I have agent data stored in a database
< Back
Next >
Finish
Cancel
New agent
Step 2. Agent animation
Choose animation:
3D
2D
None
People
Person
Office Worker
Worker
Doctor
Nurse
Technician
Policeman
Soldier
Officer
Woman 1
Woman 2
Boy
Girl
Rider
Sitting Person
< Back
Next >
Finish
Cancel

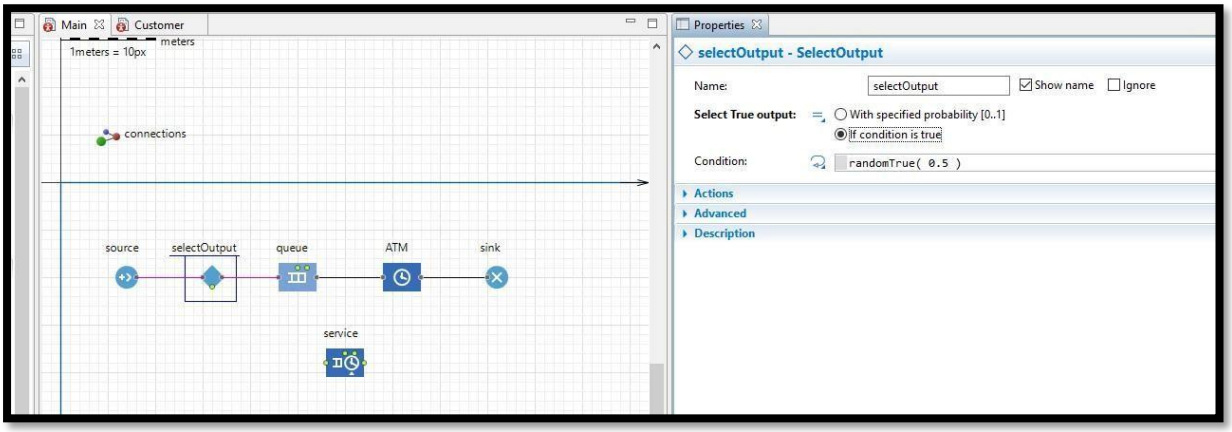

Properties
source - Source
Name:
source
Show name
Ignore
Arrivals defined by:
Rate
Arrival rate:
0.3
per minute
Set agent parameters from DB:
Multiple agents per arrival:
Limited number of arrivals:
Location of arrival:
Not specified
Agent
New agent:
Customer
Change dimensions:
Advanced
Actions
Advanced
Description

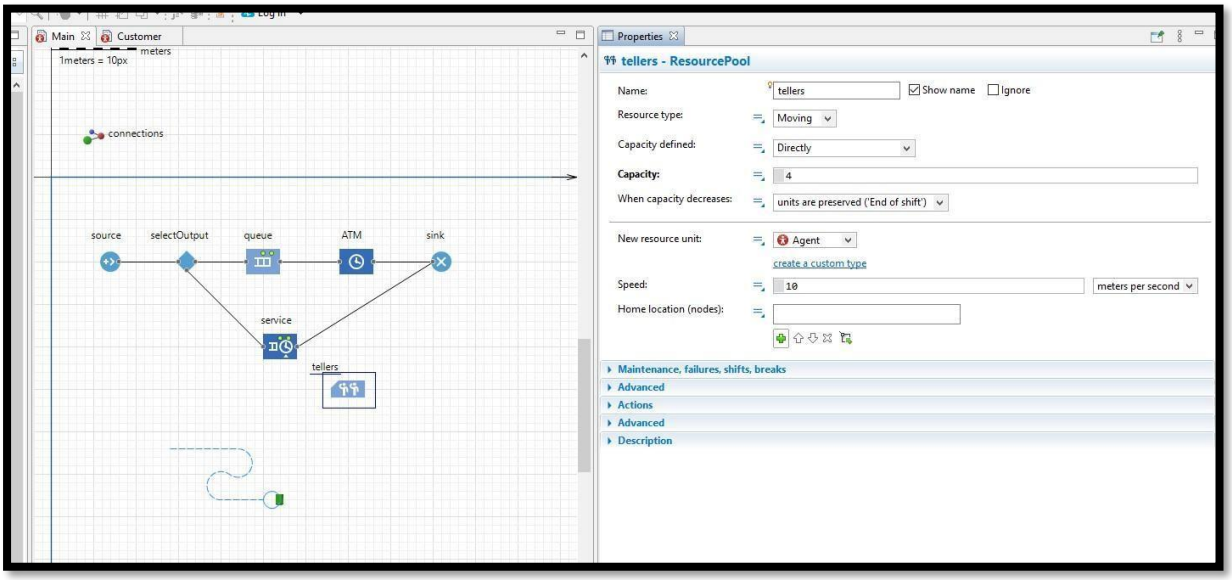

Bank : Simulation - AnyLogic Personal Learning Edition
466.07 sec 09/15/2023 00:07
200%
[window3d]
Console
Events
1.67 min/sec EPS: 2 FPS: 41 Step: 10
Running: 12.33 sec 6% of 512M
x100
Running

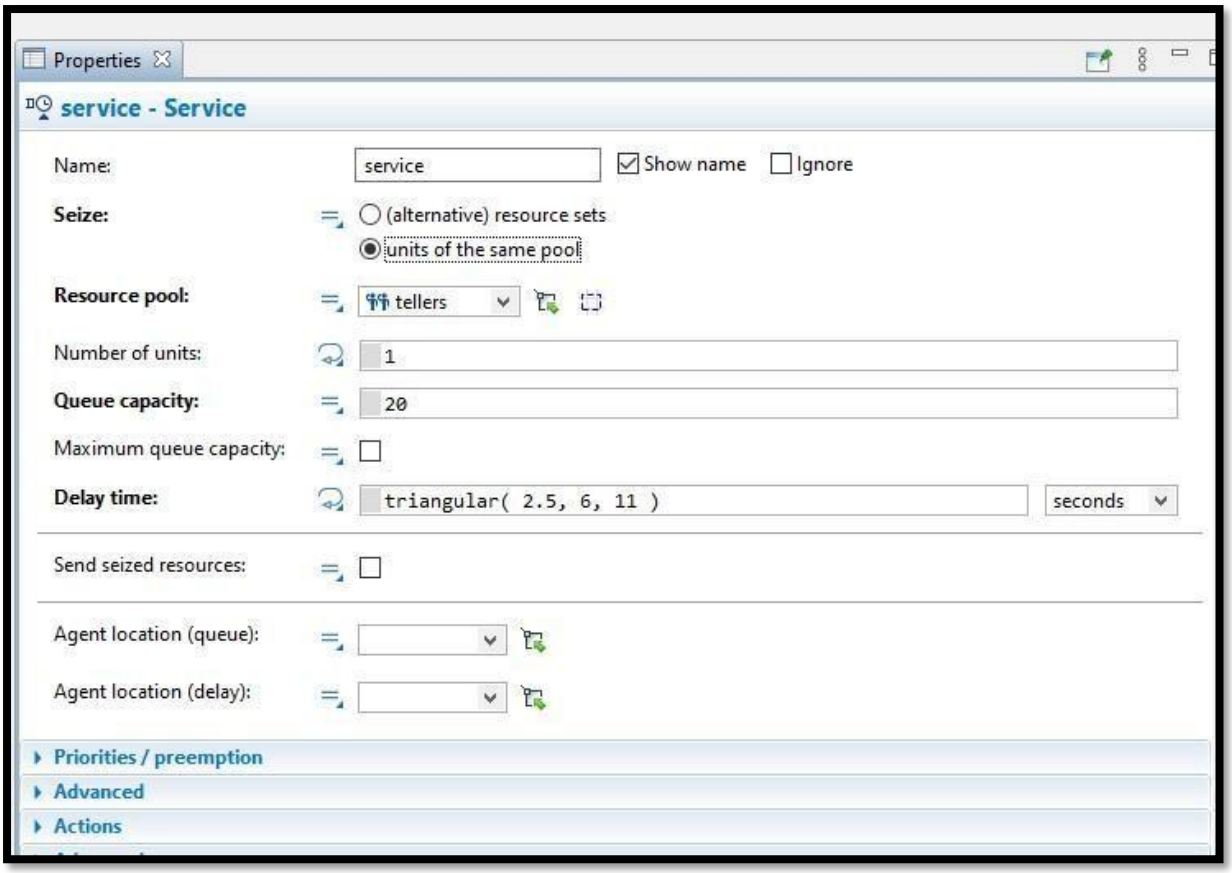

3D Objects
People
Buildings
Road Transport
Rail Transport
Maritime Transport
Military
Warehouses and Container Terminals
Health
Manufacturing
CNC Machines
Energy
Mining
Office
Supermarket
Person
Office Worker
Cart
Cash Desk
ATM
Vending Machine
Ticket Vending Machine
Bill payment machine
Locker
Locker 2
Locker 3
Security Camera
Airport
Miscellaneous
Boxes
Bottles
Roads
Tanks
Pipes
Geometric primitives
connections
source
queue
ATM
sink
atm - 3D Object
Name:
atm
Ignore
Visible on upp
Visible:
yes
File:
3d/atm.dae
Resize automatically to match agent scale
Additional scale:
100%
Orientation:
Colors
Position
Advanced
Description

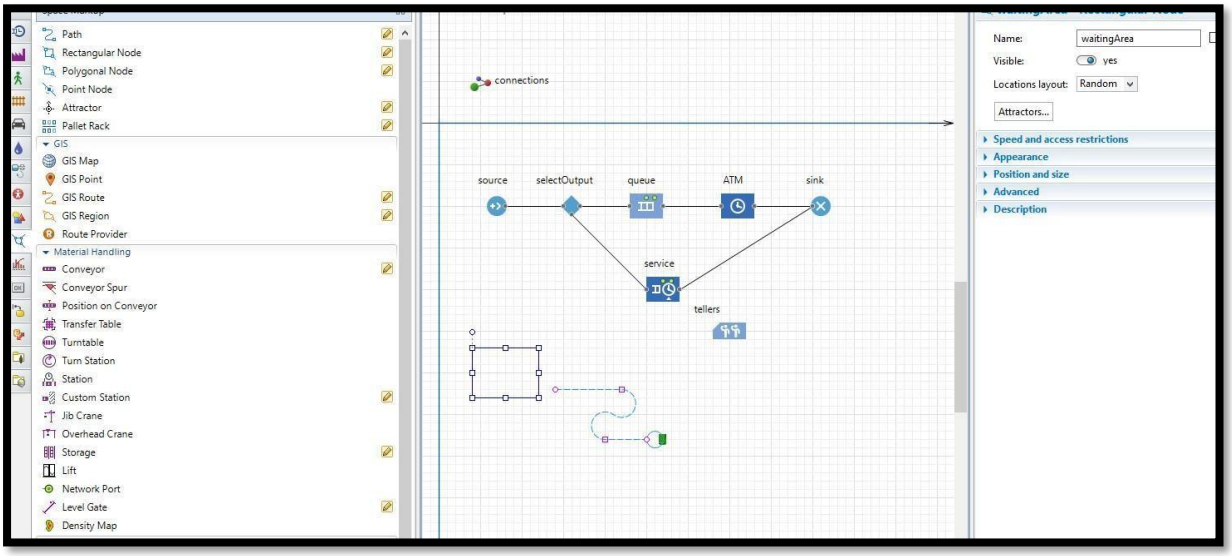

Bank : Simulation - AnyLogic Personal Learning Edition
380.98 sec
09/15/2023 00:06
200%
[window3d]
Console
Events
1.58 min/sec
EPS: 0
FPS: 41
Step: 6
Running: 21.35 sec
7% of 512M
x100
Running

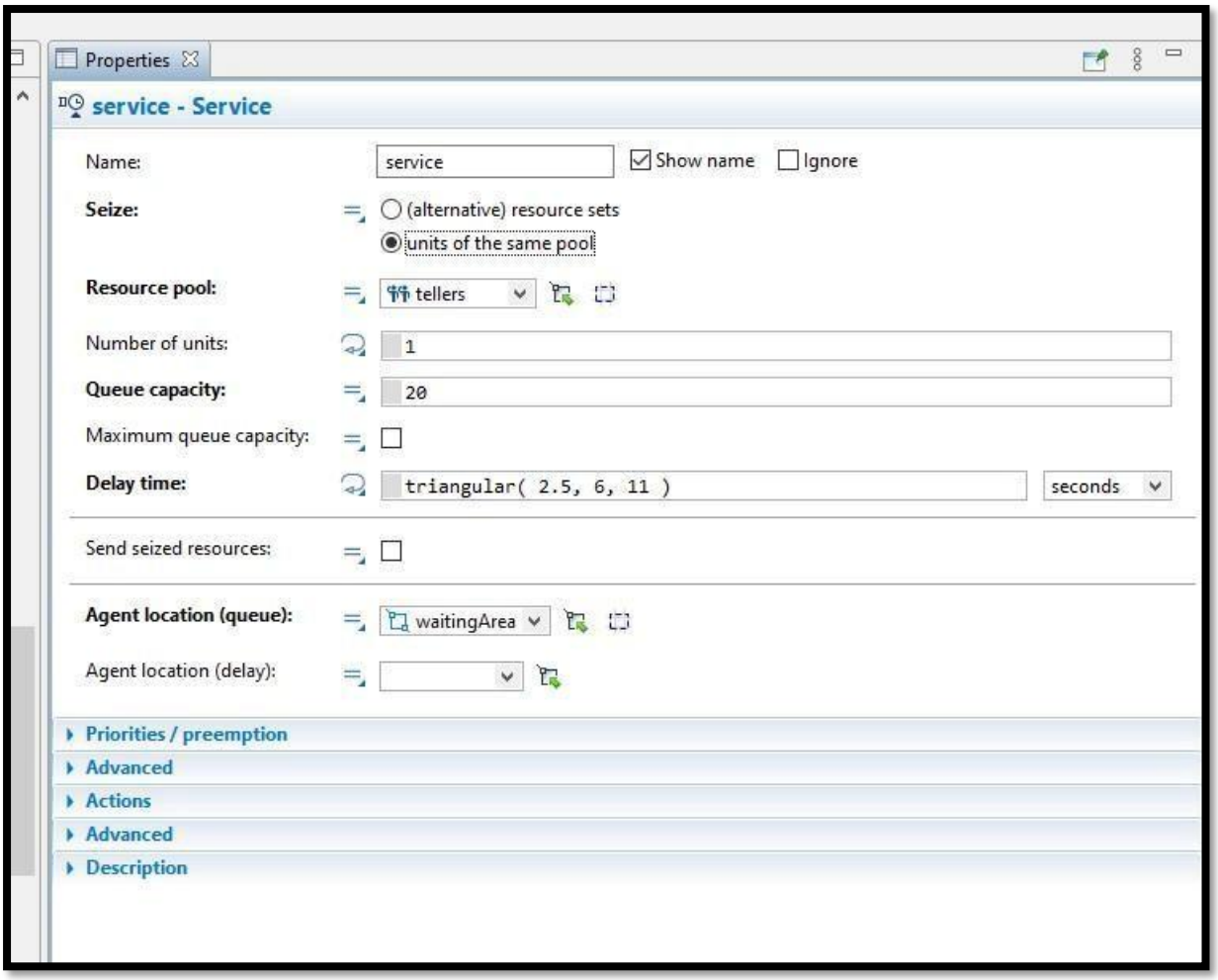

Main
Customer
1meters = 10px
meters
connections
source
queue
ATM
sink
service
Properties
service - Service
Name:
service
Show name
Ignore
Seize:
(alternative) resource sets
units of the same pool
Resource sets (alternatives):
Add list
Queue capacity:
20
Maximum queue capacity:
Delay time:
triangular(2.5, 6, 11)
seconds
Send seized resources:
Agent location (queue):
Agent location (delay):
Priorities / preemption
Advanced
Actions
Advanced
Description

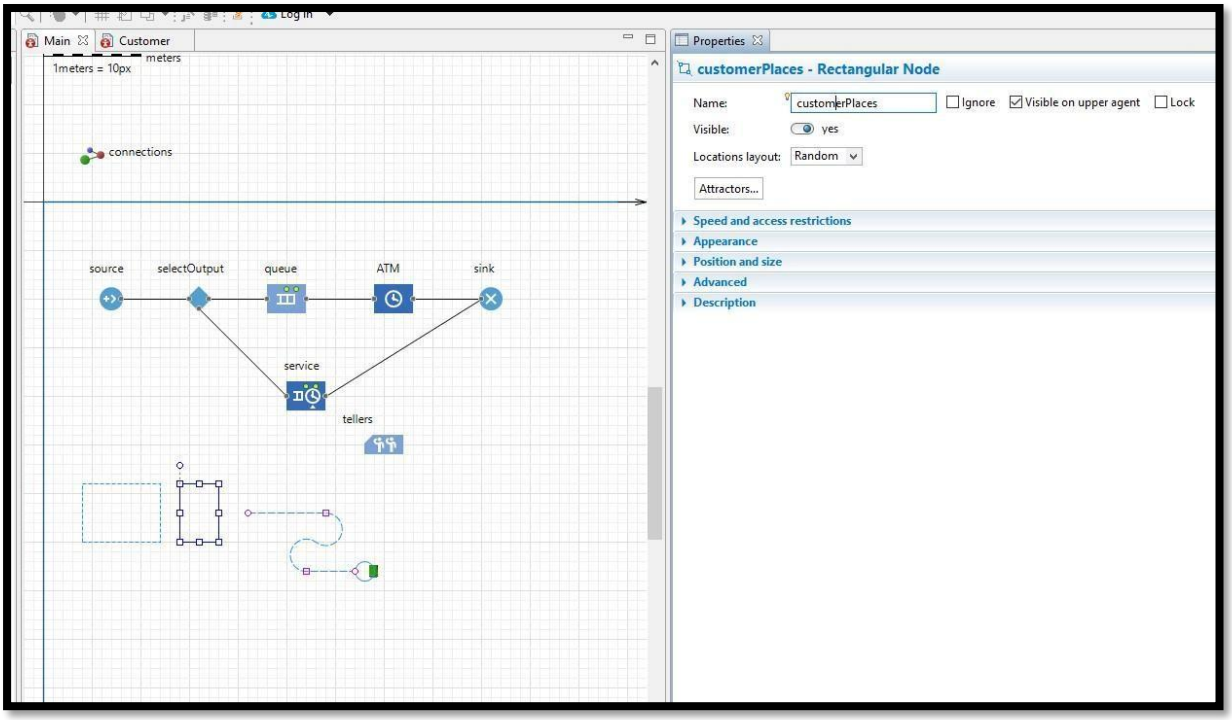

Main
Customer
1meters = 10px
meters
connections
source
selectOutput
queue
ATM
sink
service
Properties
selectOutput - SelectOutput
Name:
selectOutput
Show name
Ignore
Select True output:
With specified probability [0..1]
If condition is true
Condition:
randomTrue(0.5)
Actions
Advanced
Description

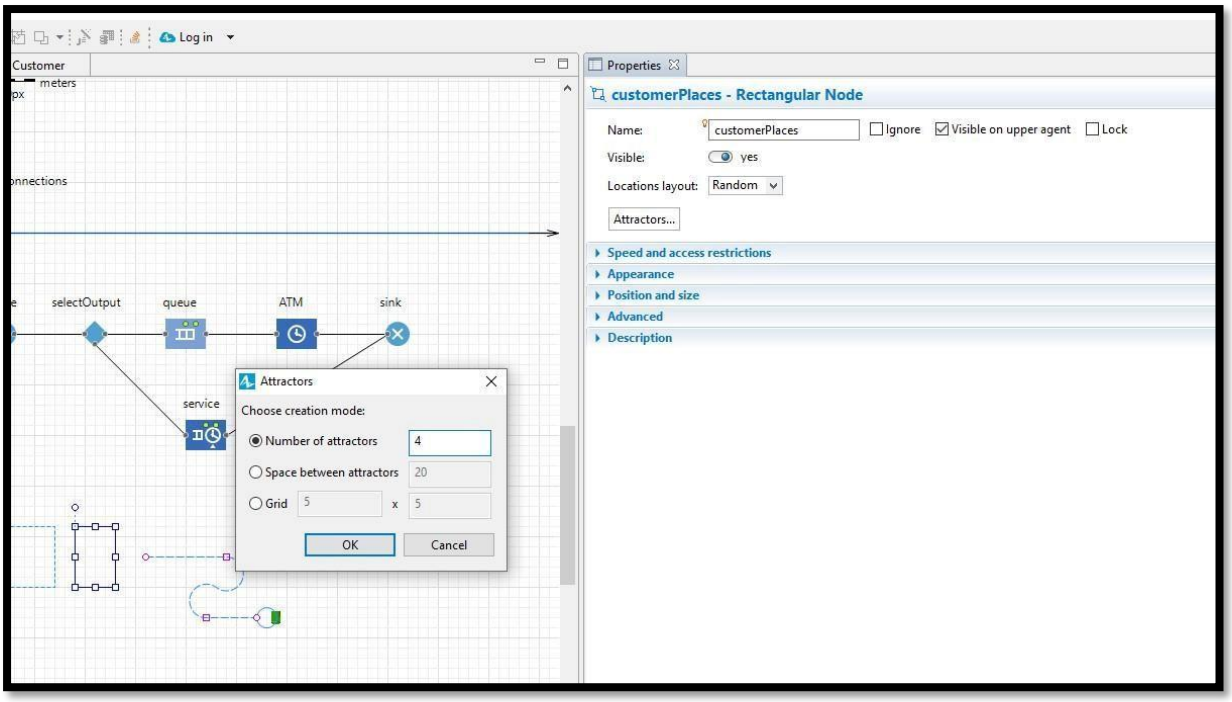

Main
Customer
1meters = 10px
meters
connections
source
selectOutput
queue
ATM
sink
service
tellers
Properties
tellers - ResourcePool
Name:
tellers
Show name
Ignore
Resource type:
Moving
Capacity defined:
Directly
Capacity:
4
When capacity decreases:
units are preserved ('End of shift')
New resource unit:
Agent
create a custom type
Speed:
10
meters per second
Home location (nodes):
Maintenance, failures, shifts, breaks
Advanced
Actions
Advanced
Description

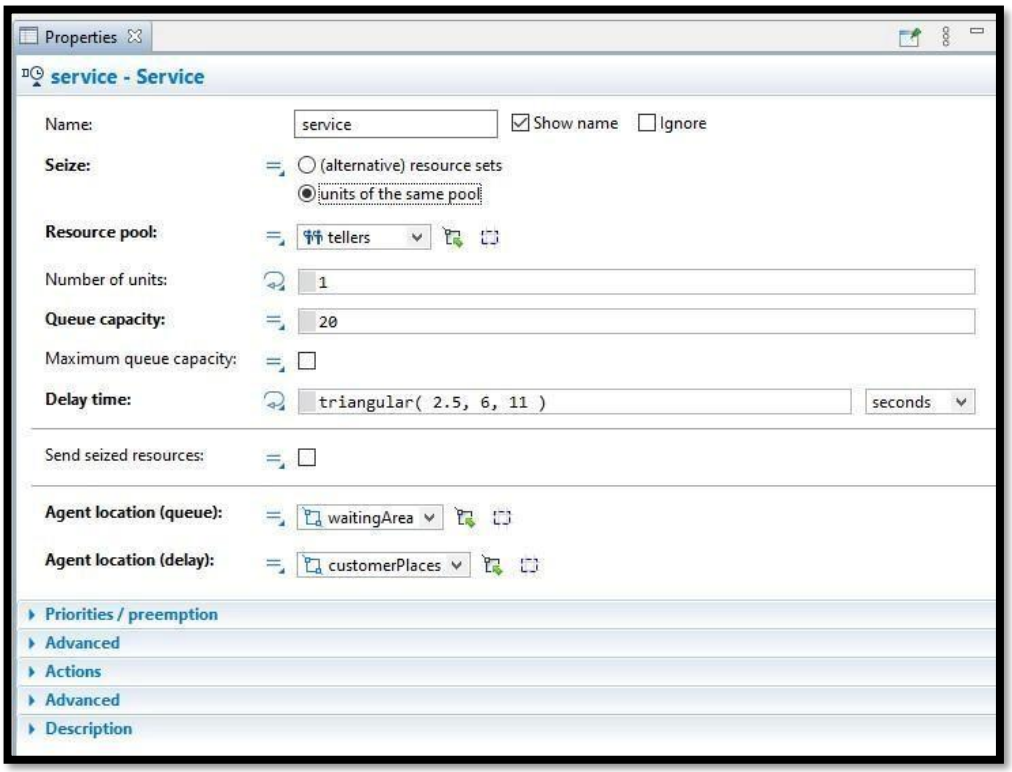

Properties
service - Service
Name:
service
Show name
Ignore
Seize:
(alternative) resource sets
units of the same pool
Resource pool:
tellers
Number of units:
1
Queue capacity:
20
Maximum queue capacity:
Delay time:
triangular(2.5, 6, 11)
seconds
Send seized resources:
Agent location (queue):
Agent location (delay):
Priorities / preemption
Advanced
Actions

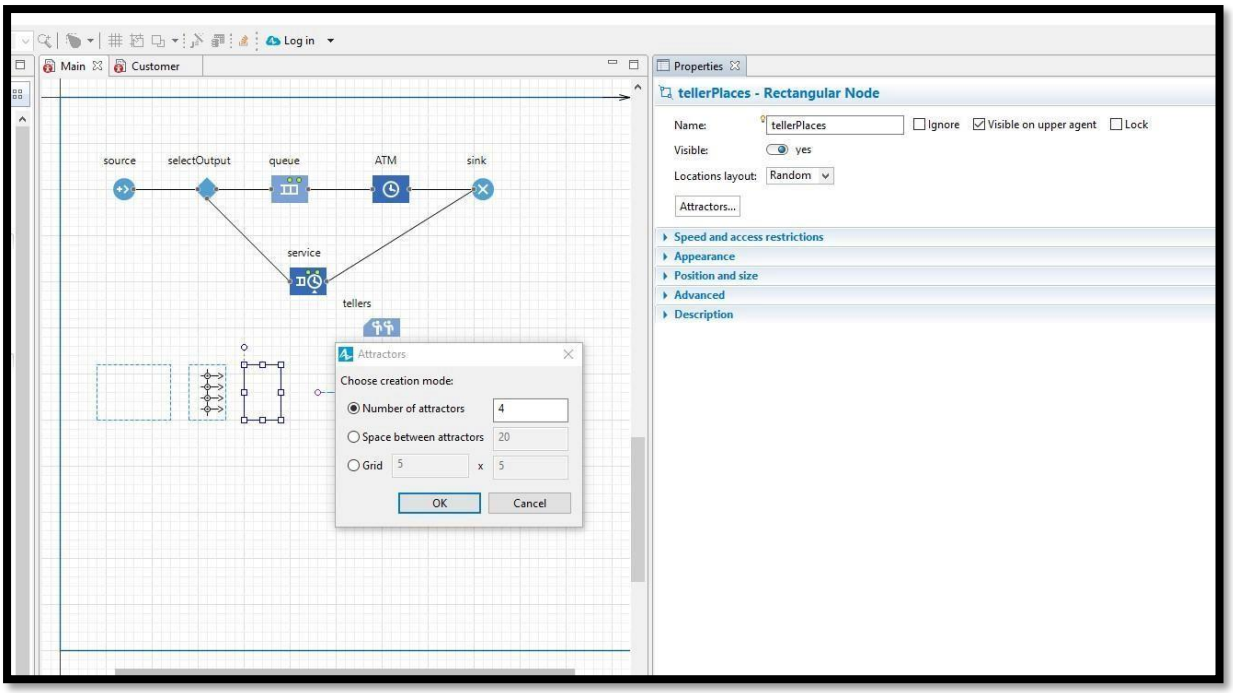

Path
Rectangular Node
Polygonal Node
Point Node
Attractor
Pallet Rack
GIS
GIS Map
GIS Point
GIS Route
GIS Region
Route Provider
Material Handling
Conveyor
Conveyor Spur
Position on Conveyor
Transfer Table
Turntable
Turn Station
Station
Custom Station
Jib Crane
Overhead Crane
Storage
Lift
Network Port
Level Gate
Density Map
connections
source
selectOutput
queue
ATM
sink
service
tellers
Name:
waitingArea
Visible:
yes
Locations layout:
Random
Attractors...
Speed and access restrictions
Appearance
Position and size
Advanced
Description

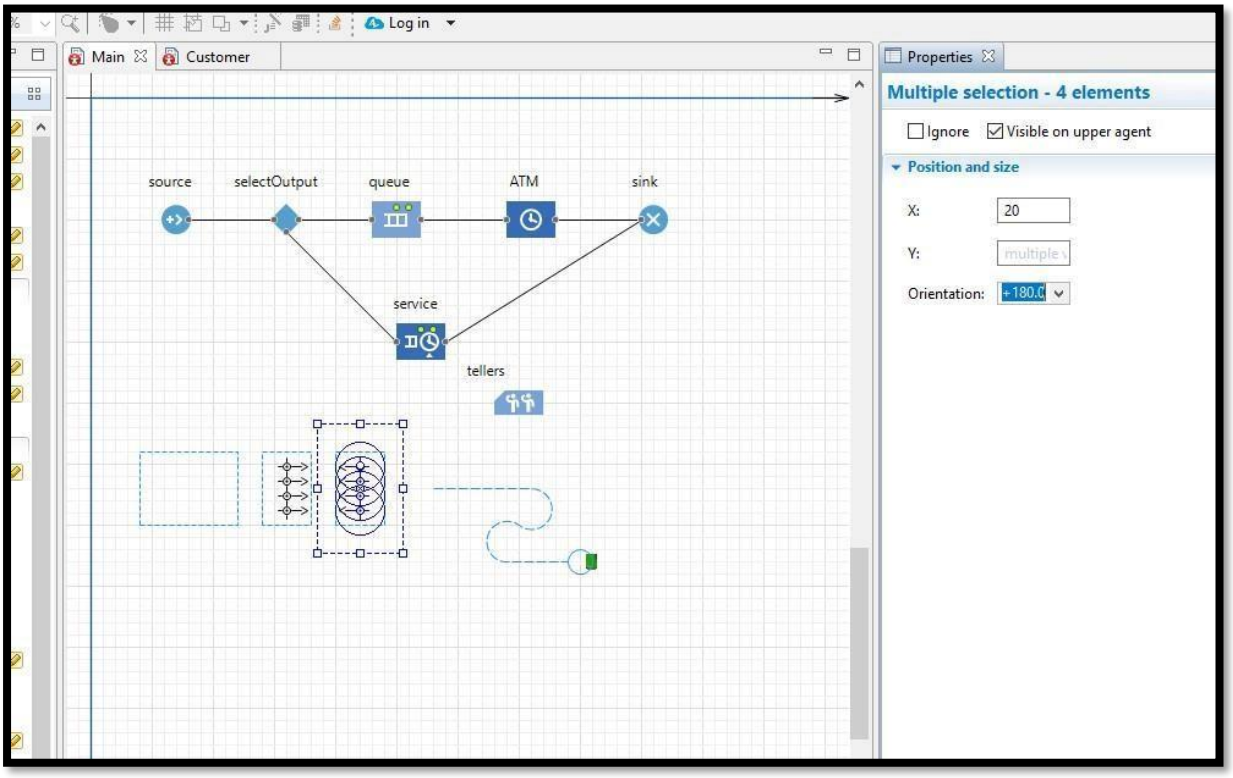

Properties
service - Service
Name:
service
Show name
Ignore
Seize:
(alternative) resource sets
units of the same pool
Resource pool:
tellers
Number of units:
1
Queue capacity:
20
Maximum queue capacity:
Delay time:
triangular(2.5, 6, 11)
seconds
Send seized resources:
Agent location (queue):
waitingArea
Agent location (delay):
Priorities / preemption
Advanced
Actions
Advanced
Description

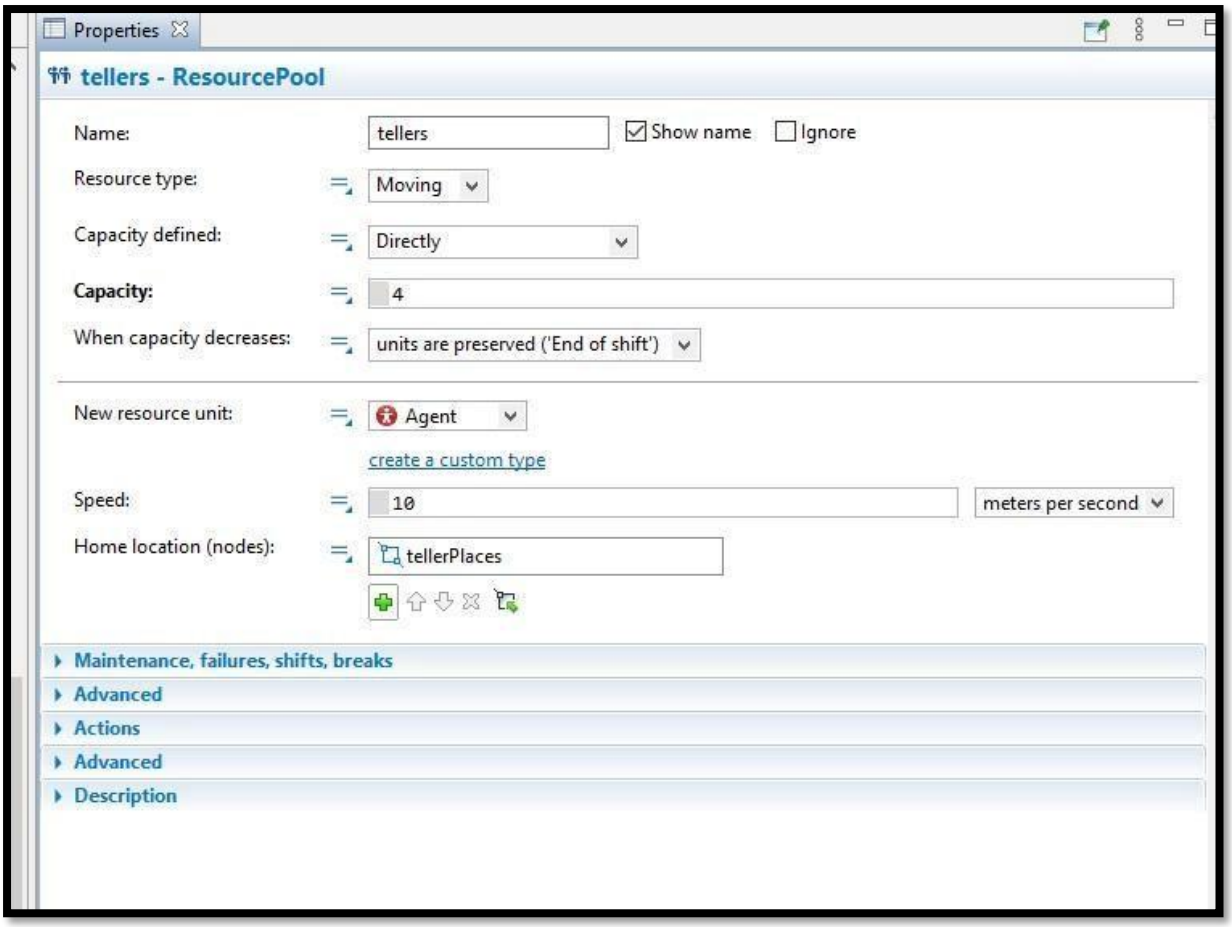

Main
Customer
meters
1meters = 10px
connections
source
selectOutput
queue
ATM
sink
service
tellers
Properties
customerPlaces - Rectangular Node
Name:
customerPlaces
Ignore
Visible on upper agent
Lock
Visible:
yes
Locations layout:
Random
Attractors...
Speed and access restrictions
Appearance
Position and size
Advanced
Description

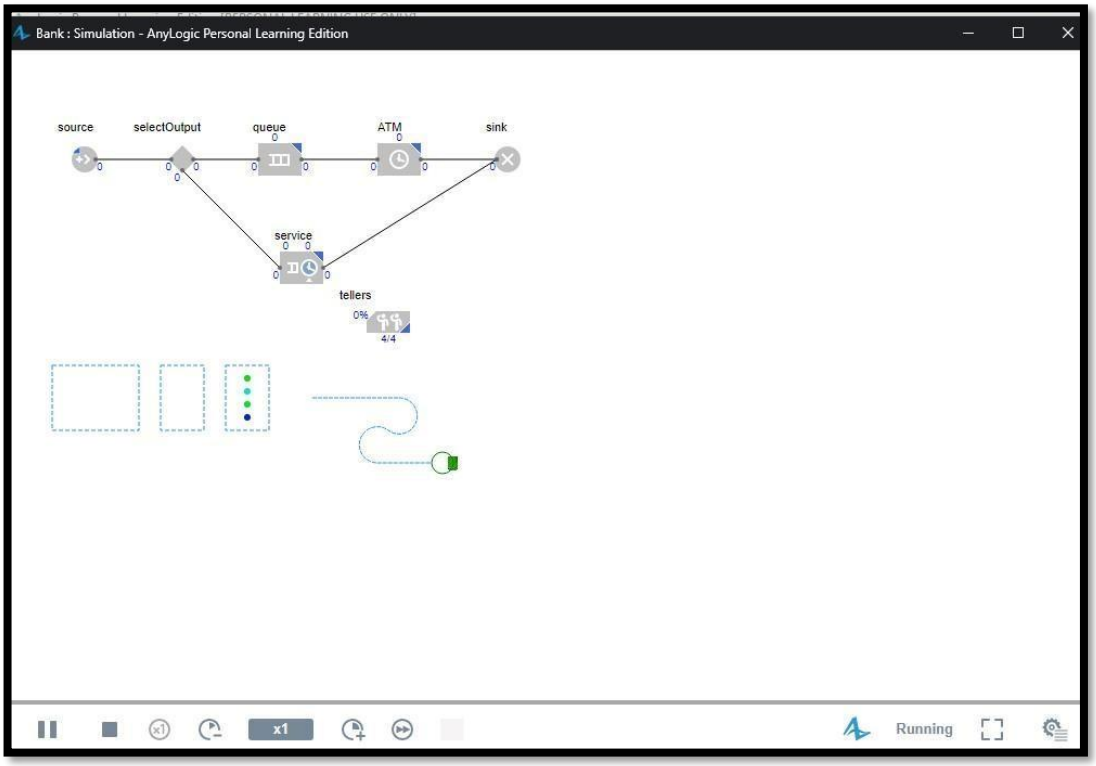

Log in
Customer
meters
selectOutput
queue
ATM
sink
service
Attractors
Choose creation mode:
Number of attractors
4
Space between attractors
20
Grid
5
x
5
OK
Cancel
Properties
customerPlaces - Rectangular Node
Name:
customerPlaces
Ignore
Visible on upper agent
Lock
Visible:
yes
Locations layout:
Random
Attractors...
Speed and access restrictions
Appearance
Position and size
Advanced
Description

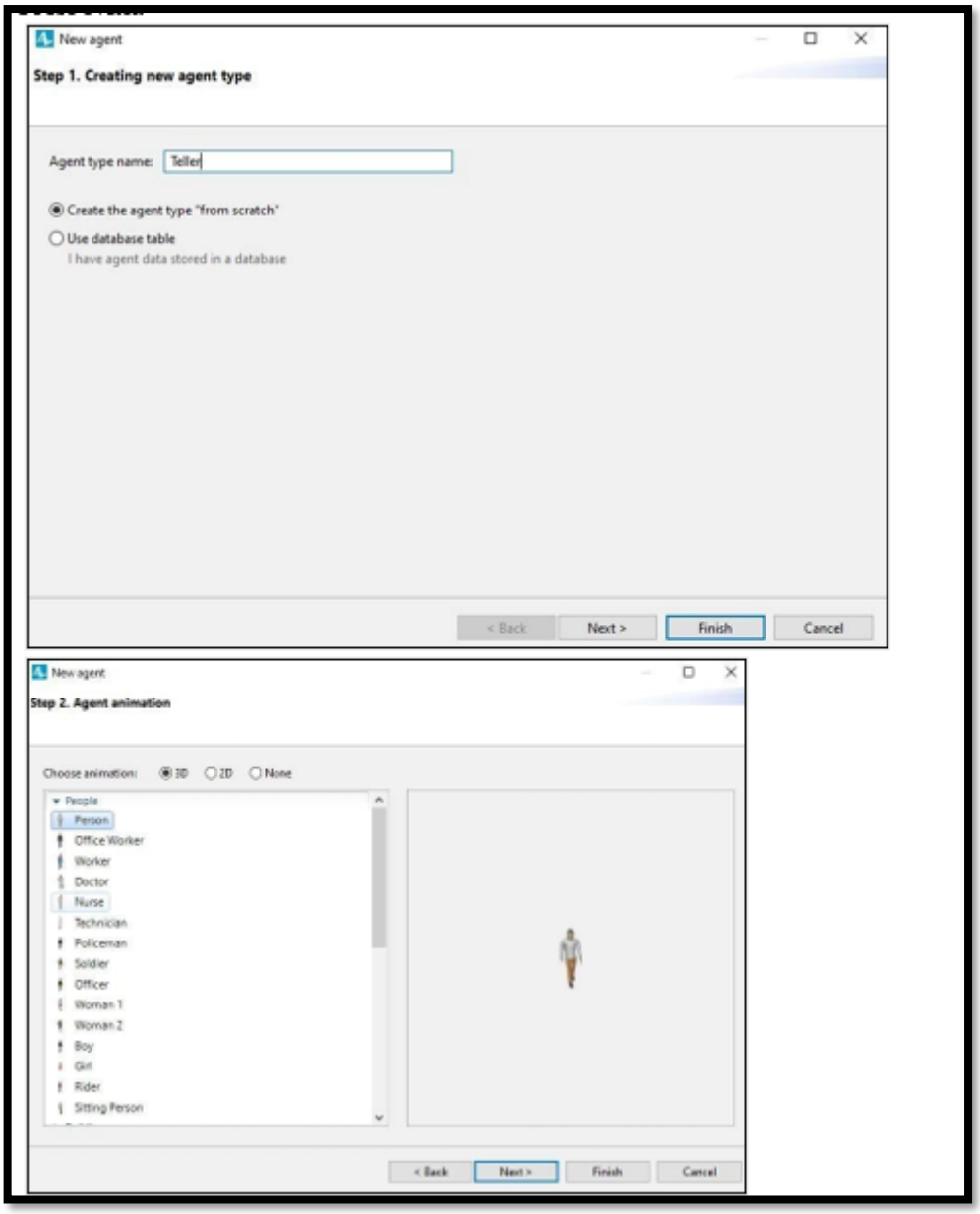

Properties
service - Service
Name:
service
Show name
Ignore
Seize:
(alternative) resource sets
units of the same pool
Resource pool:
tellers
Number of units:
1
Queue capacity:
20
Maximum queue capacity:
Delay time:
triangular(2.5, 6, 11)
seconds
Send seized resources:
Agent location (queue):
waitingArea
Agent location (delay):
customerPlaces
Priorities / preemption
Advanced
Actions
Advanced
Description

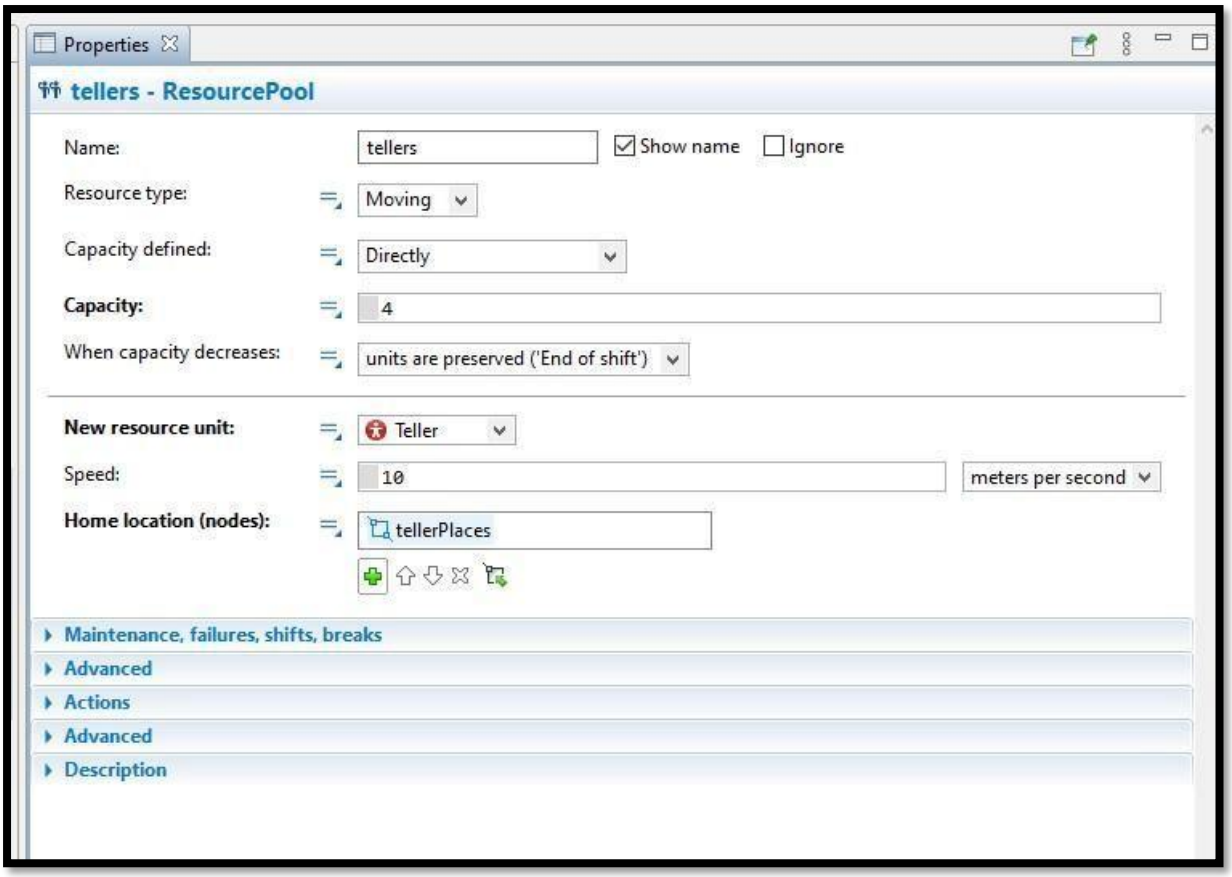

Log in
Main
Customer
source
selectOutput
queue
ATM
sink
service
tellers
Attractors
Choose creation mode:
Number of attractors
4
Space between attractors
20
Grid
5
x
5
OK
Cancel
Properties
tellerPlaces - Rectangular Node
Name:
tellerPlaces
Ignore
Visible on upper agent
Lock
Visible:
yes
Locations layout:
Random
Attractors...
Speed and access restrictions
Appearance
Position and size
Advanced
Description

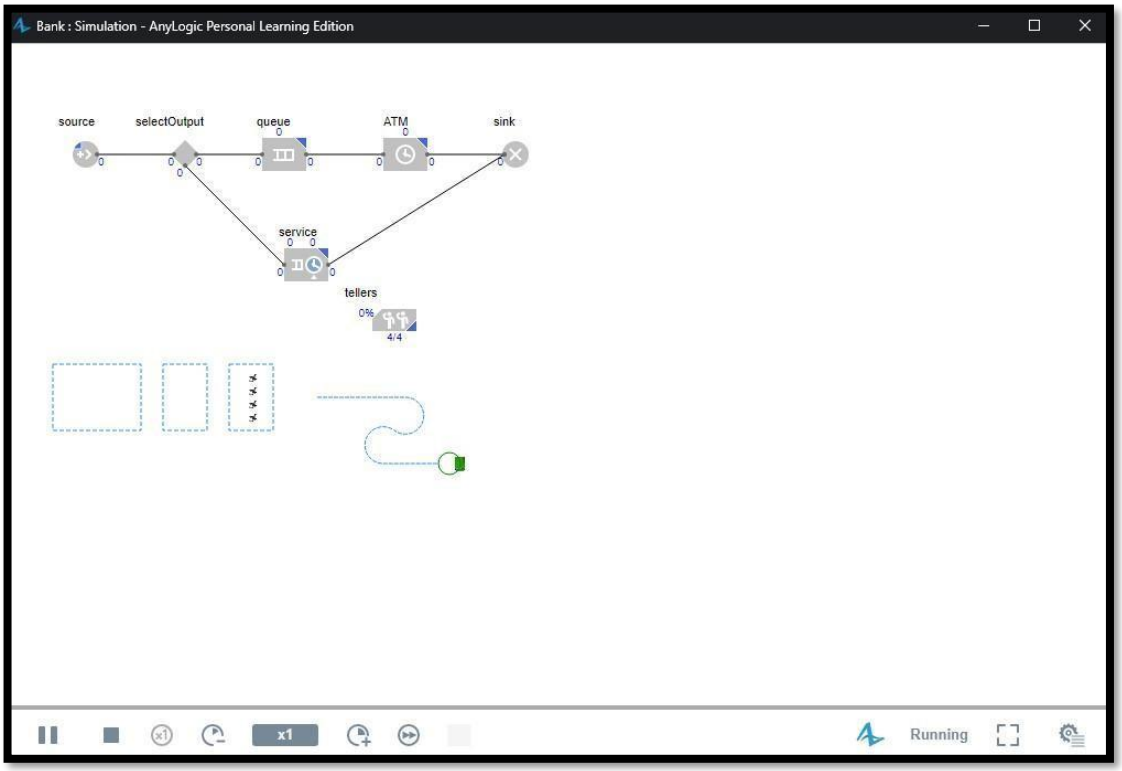

Log in
Main
Customer
source
selectOutput
queue
ATM
sink
service
tellers
Properties
Multiple selection - 4 elements
Ignore
Visible on upper agent
Position and size
X:
20
Y:
Orientation:
+180.0

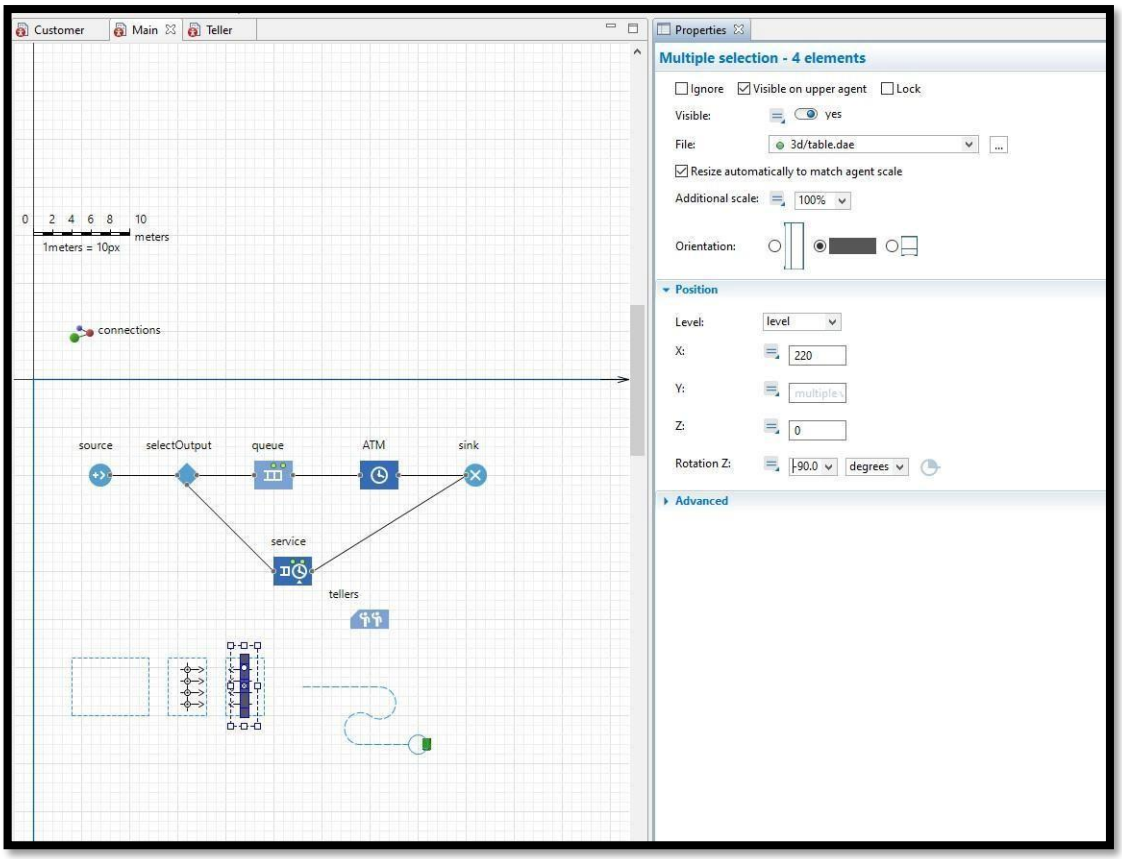

Properties
tellers - ResourcePool
Name:
tellers
Show name
Ignore
Resource type:
Moving
Capacity defined:
Directly
Capacity:
4
When capacity decreases:
units are preserved ('End of shift')
New resource unit:
Agent
create a custom type
Speed:
10
meters per second
Home location (nodes):
tellerPlaces
Maintenance, failures, shifts, breaks
Advanced
Actions
Advanced
Description

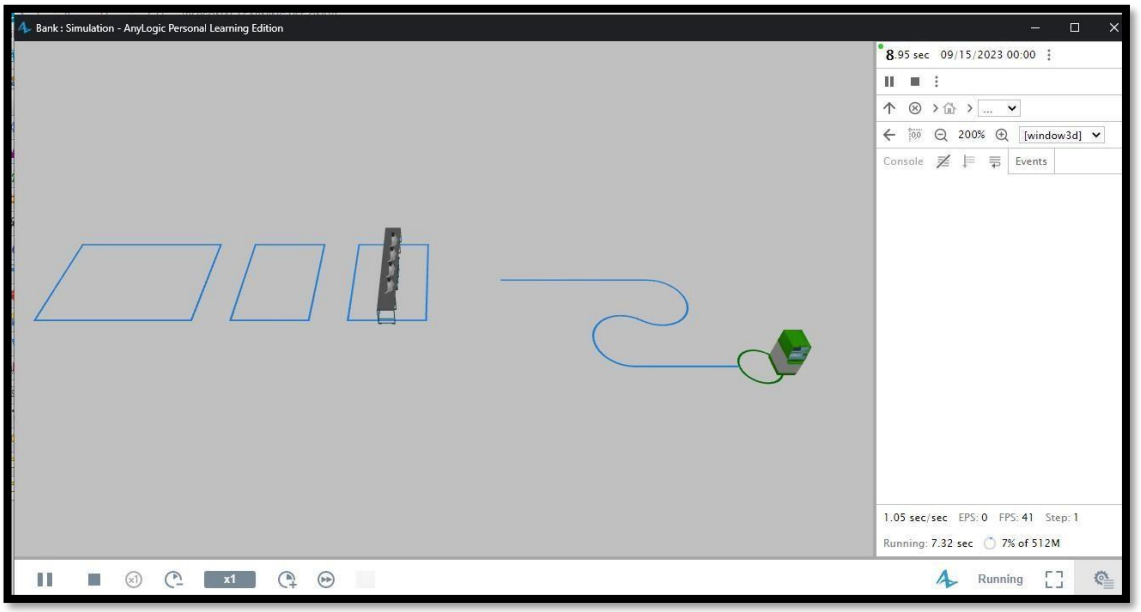

Bank : Simulation - AnyLogic Personal Learning Edition
source
selectOutput
queue
ATM
sink
service
tellers
0%
4/4
x1
Running

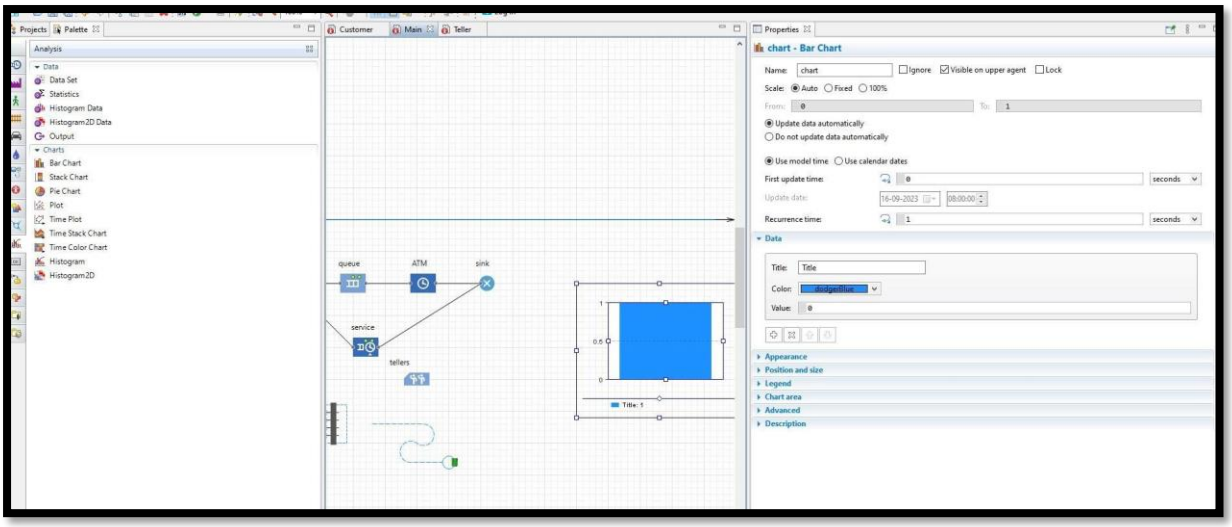

New agent
Step 1. Creating new agent type
Agent type name:
Teller
Create the agent type "from scratch"
Use database table
I have agent data stored in a database
< Back
Next >
Finish
Cancel
New agent
Step 2. Agent animation
Choose animation:
3D
2D
None
People
Person
Office Worker
Worker
Doctor
Nurse
Technician
Policeman
Soldier
Officer
Woman 1
Woman 2
Boy
Girl
Rider
Sitting Person
< Back
Next >
Finish
Cancel

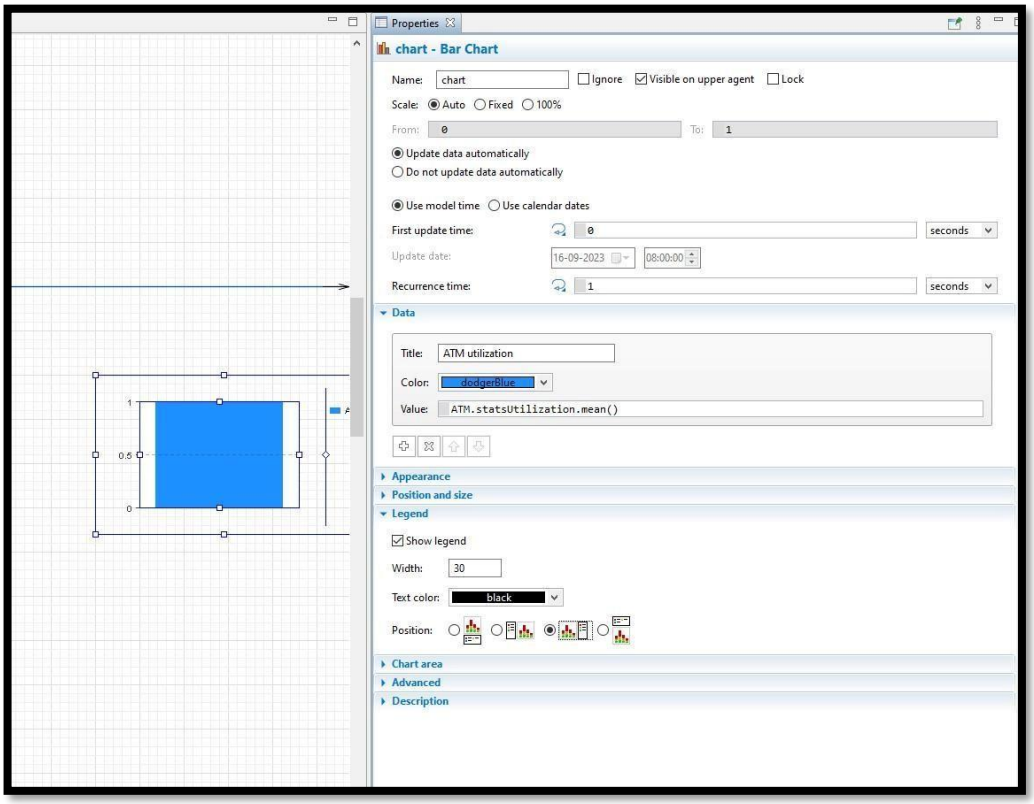

Properties
tellers - ResourcePool
Name:
tellers
Show name
Ignore
Resource type:
Moving
Capacity defined:
Directly
Capacity:
4
When capacity decreases:
units are preserved ('End of shift')
New resource unit:
Teller
Speed:
10
meters per second
Home location (nodes):
tellerPlaces
Maintenance, failures, shifts, breaks
Advanced
Actions
Advanced
Description

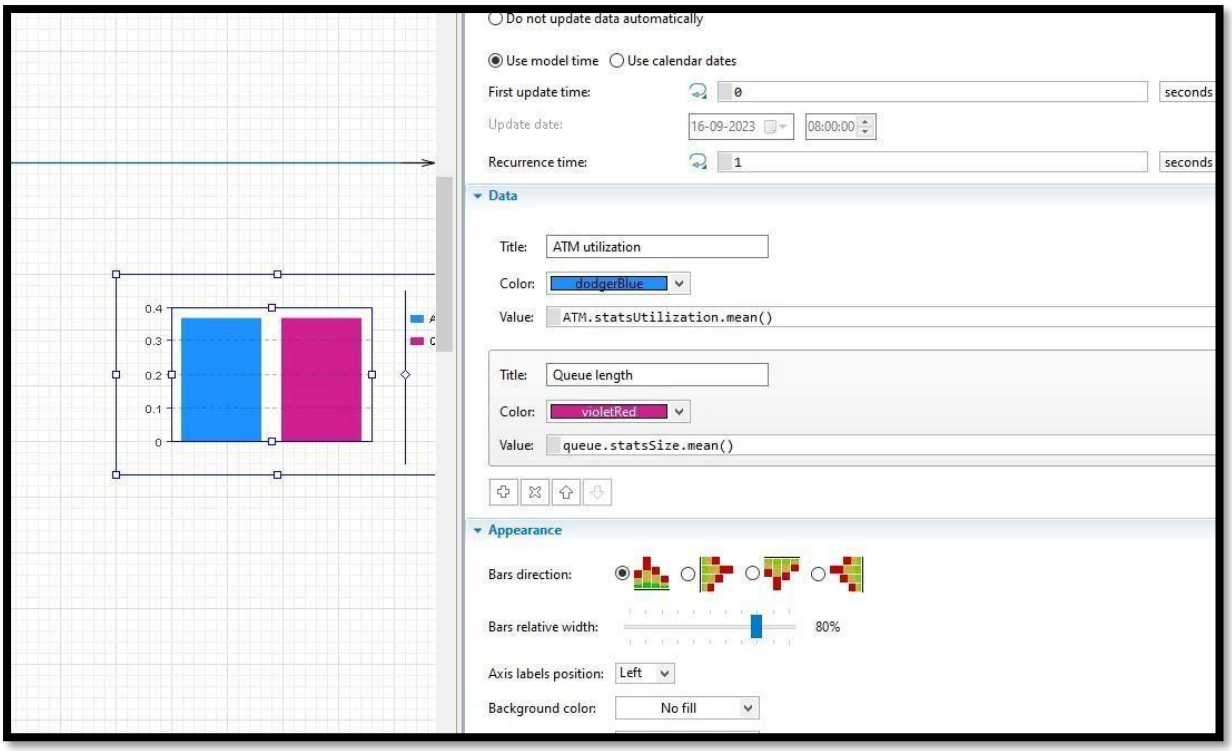

Bank : Simulation - AnyLogic Personal Learning Edition
source
selectOutput
queue
ATM
sink
service
tellers
0%
4/4
x1
Running

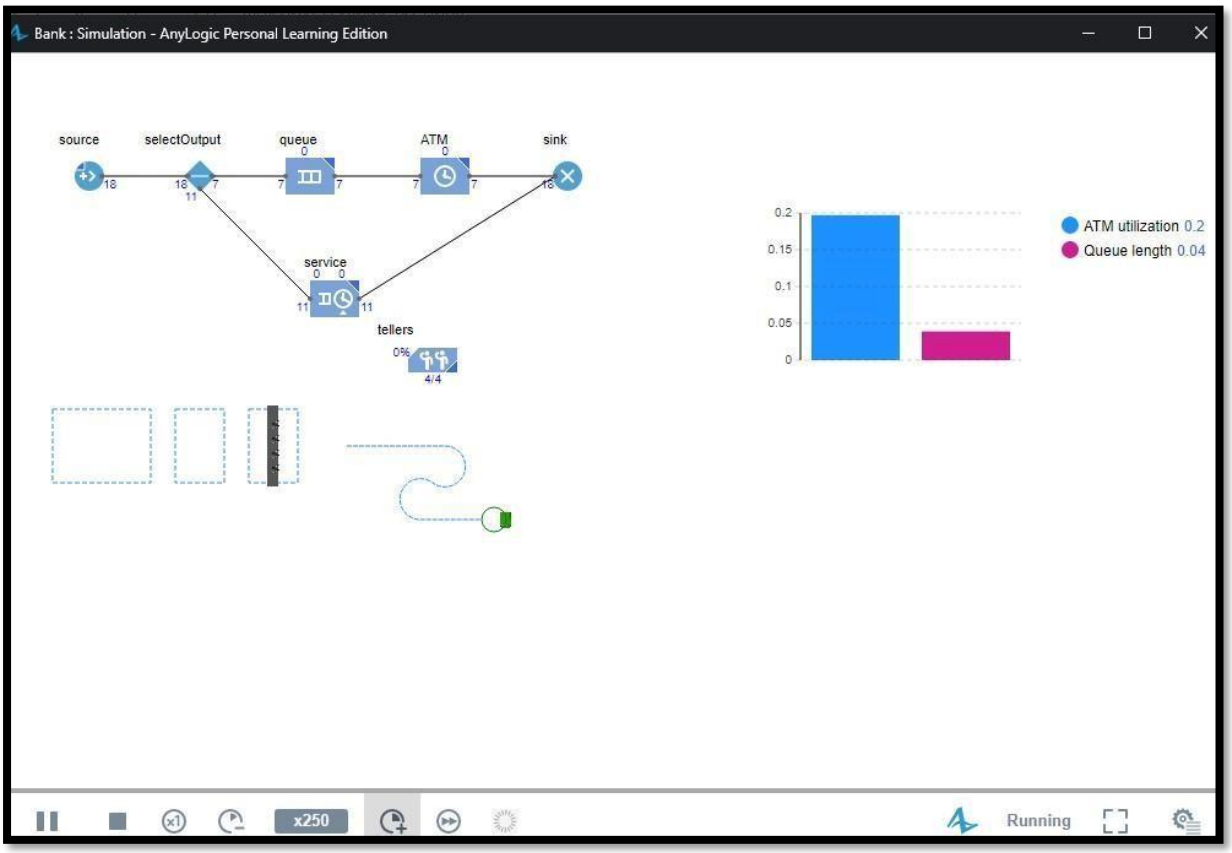

Customer
Main
Teller
Properties
Multiple selection - 4 elements
Ignore
Visible on upper agent
Lock
Visible:
yes
File:
3d/table.dae
Resize automatically to match agent scale
Additional scale:
100%
Orientation:
Position
Level:
level
X:
220
Y:
Z:
0
Rotation Z:
-90.0
degrees
Advanced
0 2 4 6 8 10
meters
1meters = 10px
connections
source
selectOutput
queue
ATM
sink
service
tellers

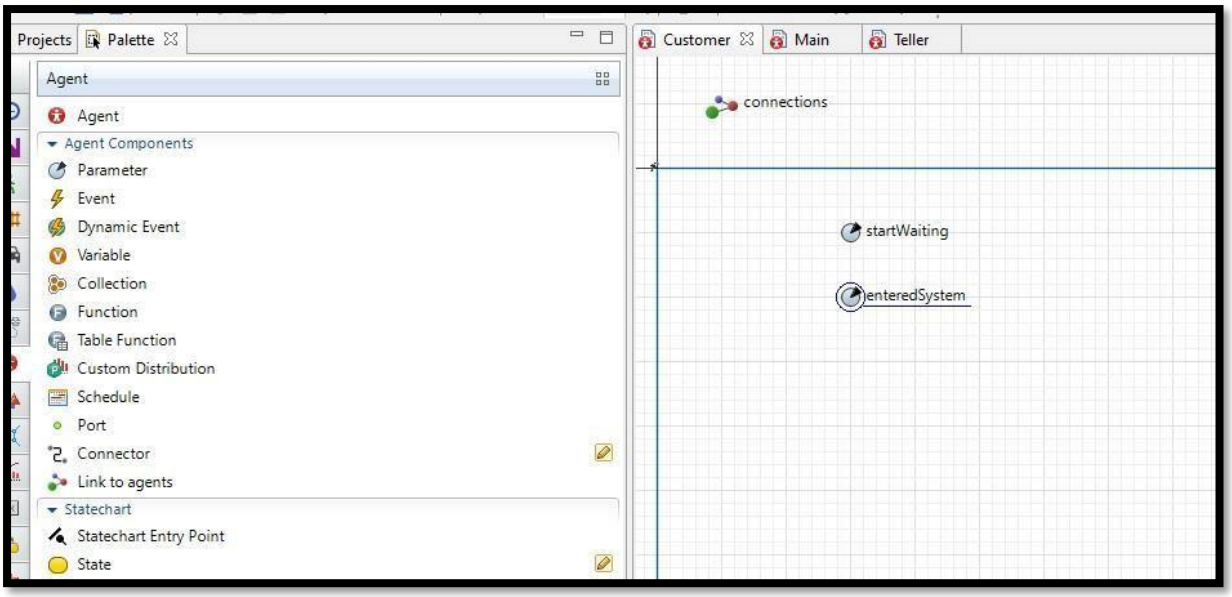

Bank : Simulation - AnyLogic Personal Learning Edition
8.95 sec 09/15/2023 00:00
200%
[window3d]
Console
Events
1.05 sec/sec EPS: 0 FPS: 41 Step: 1
Running: 7.32 sec 7% of 512M
x1
Running

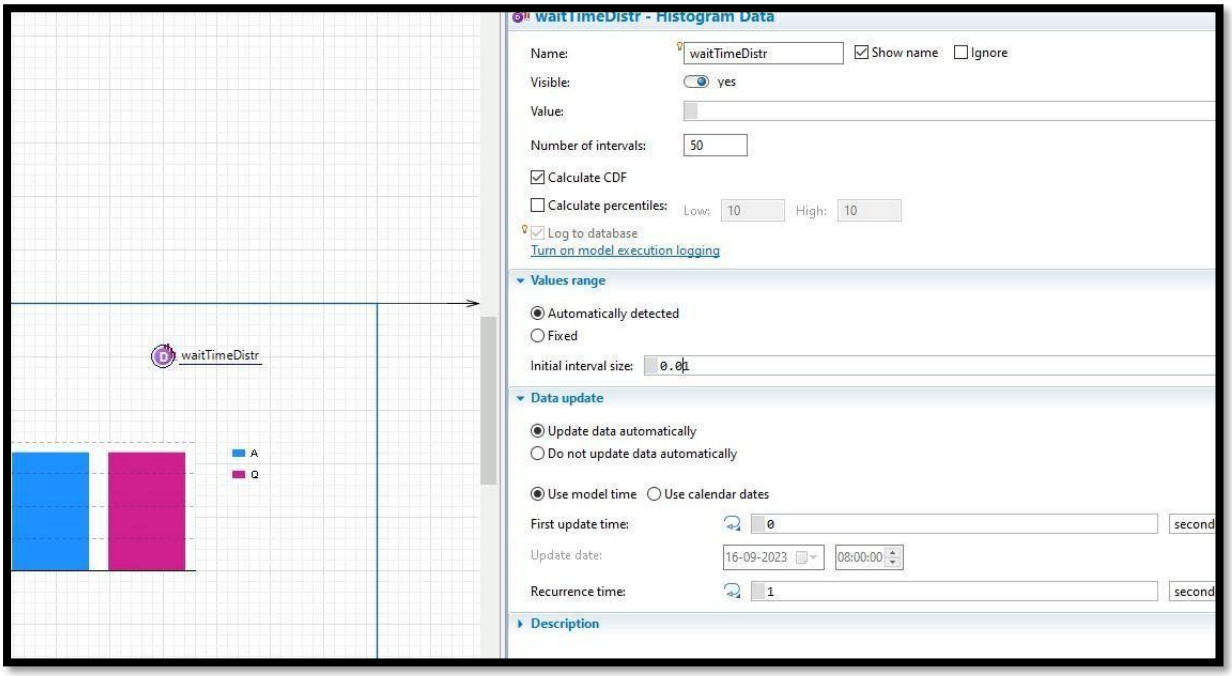

Projects
Palette
Analysis
Data
Data Set
Statistics
Histogram Data
Histogram2D Data
Output
Charts
Bar Chart
Stack Chart
Pie Chart
Plot
Time Plot
Time Stack Chart
Time Color Chart
Histogram
Histogram2D
Customer
Main
Teller
queue
ATM
sink
service
tellers
Properties
chart - Bar Chart
Name: chart
Ignore
Visible on upper agent
Lock
Scale: Auto Fixed 100%
From: 0
To: 1
Update data automatically
Do not update data automatically
Use model time
Use calendar dates
First update time:
seconds
Update date:
16-09-2023
08:00:00
Recurrence time:
1
Data
Title: Title
Color: dodgerBlue
Value: 0
Appearance
Position and size
Legend
Chart area
Advanced
Description

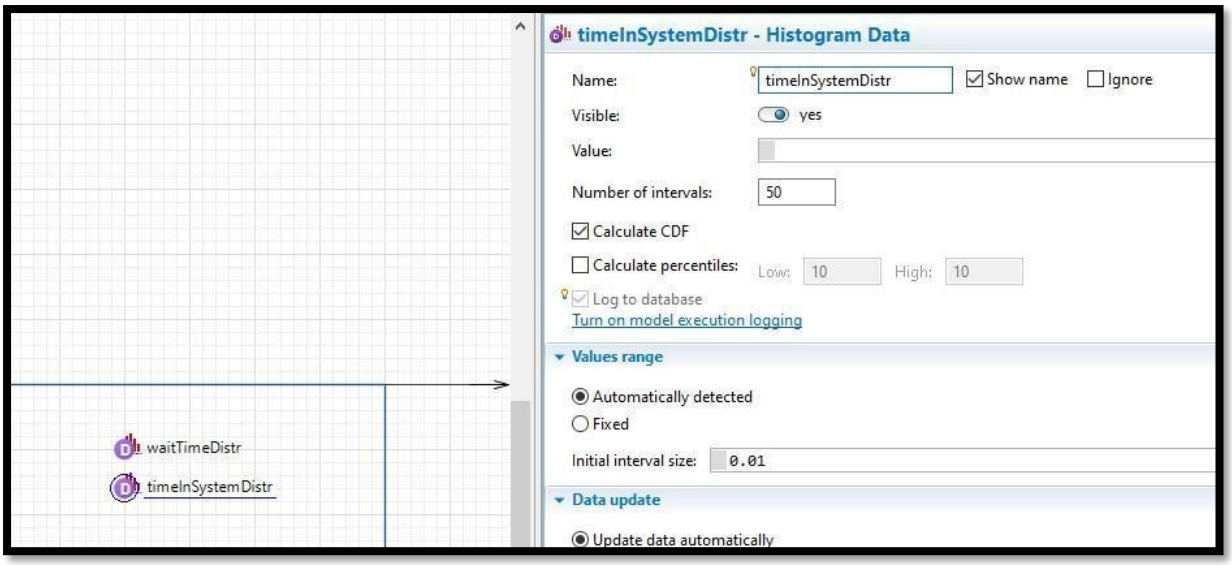

Properties
chart - Bar Chart
Name: chart
Ignore
Visible on upper agent
Lock
Scale: Auto Fixed 100%
From: 0
To: 1
Update data automatically
Do not update data automatically
Use model time
Use calendar dates
First update time: 0
seconds
Update date: 16-09-2023 08:00:00
Recurrence time: 1
seconds
Data
Title: ATM utilization
Color: dodgerBlue
Value: ATM.statsUtilization.mean()
Appearance
Position and size
Legend
Show legend
Width: 30
Text color: black
Position:
Chart area
Advanced
Description

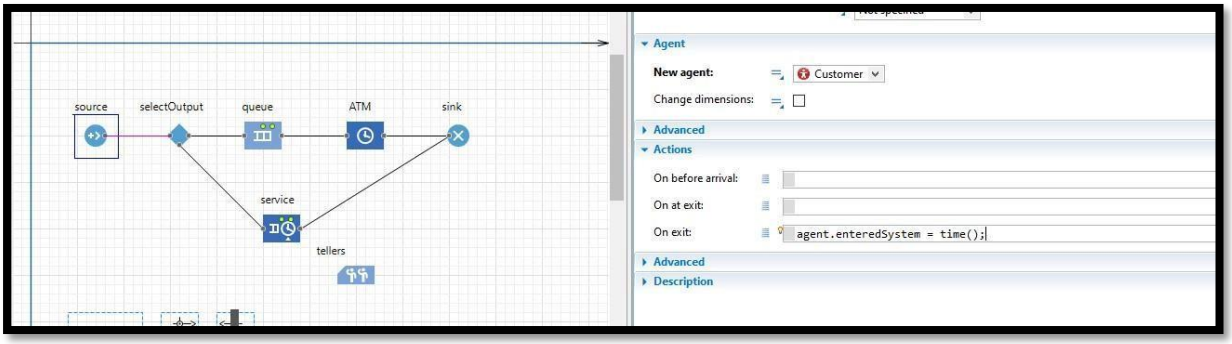

Do not update data automatically
Use model time
Use calendar dates
First update time:
0
seconds
Update date:
16-09-2023
08:00:00
Recurrence time:
1
seconds
Data
Title:
ATM utilization
Color:
dodgerBlue
Value:
ATM.statsUtilization.mean()
Title:
Queue length
Color:
violetRed
Value:
queue.statsSize.mean()
Appearance
Bars direction:
Bars relative width:
80%
Axis labels position:
Left
Background color:
No fill
0.4
0.3
0.2
0.1
0

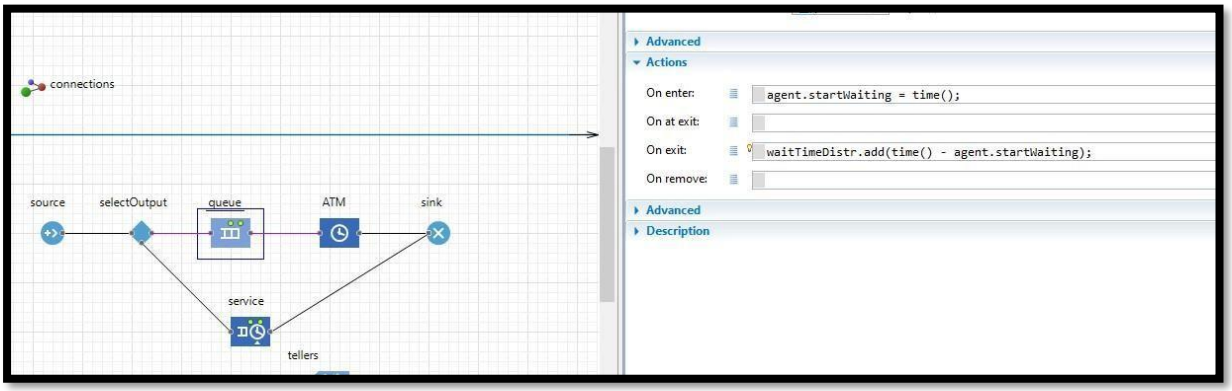

Bank : Simulation - AnyLogic Personal Learning Edition
source
selectOutput
queue
ATM
sink
service
tellers
0%
4/4
0.2
0.15
0.1
0.05
0
ATM utilization 0.2
Queue length 0.04
x250
Running

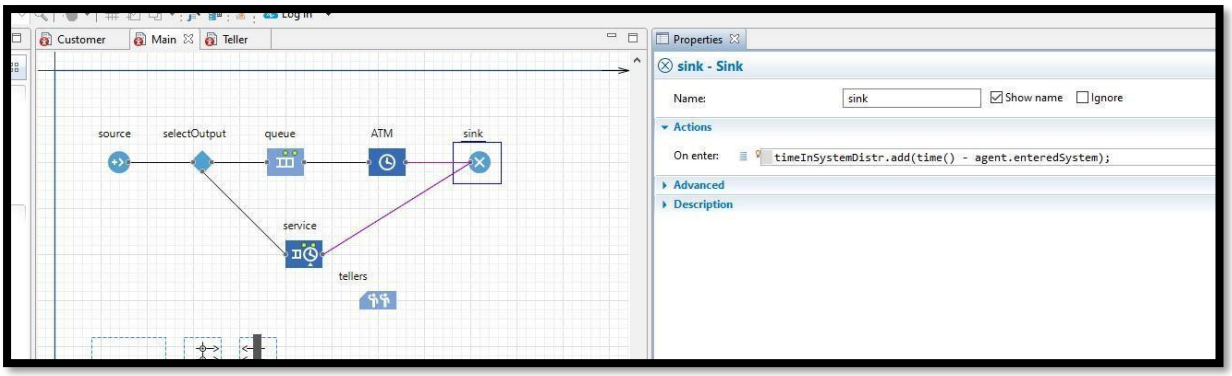

Projects
Palette
Agent
Agent
Agent Components
Parameter
Event
Dynamic Event
Variable
Collection
Function
Table Function
Custom Distribution
Schedule
Port
Connector
Link to agents
Statechart
Statechart Entry Point
State
Customer
Main
Teller
connections
startWaiting
enteredSystem

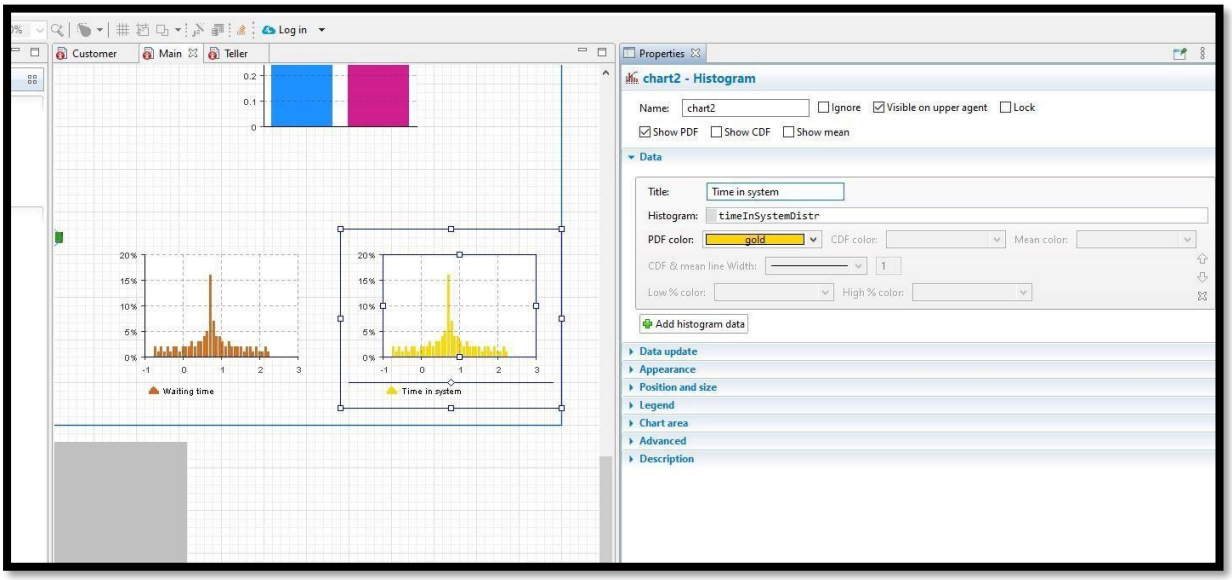

waitTimeDistr
A
Q
waitTimeDistr - Histogram Data
Name:
waitTimeDistr
Show name
Ignore
Visible:
yes
Value:
Number of intervals:
50
Calculate CDF
Calculate percentiles:
Low:
10
High:
10
Log to database
Turn on model execution logging
Values range
Automatically detected
Fixed
Initial interval size:
0.01
Data update
Update data automatically
Do not update data automatically
Use model time
Use calendar dates
First update time:
0
Update date:
16-09-2023
08:00:00
Recurrence time:
1
Description

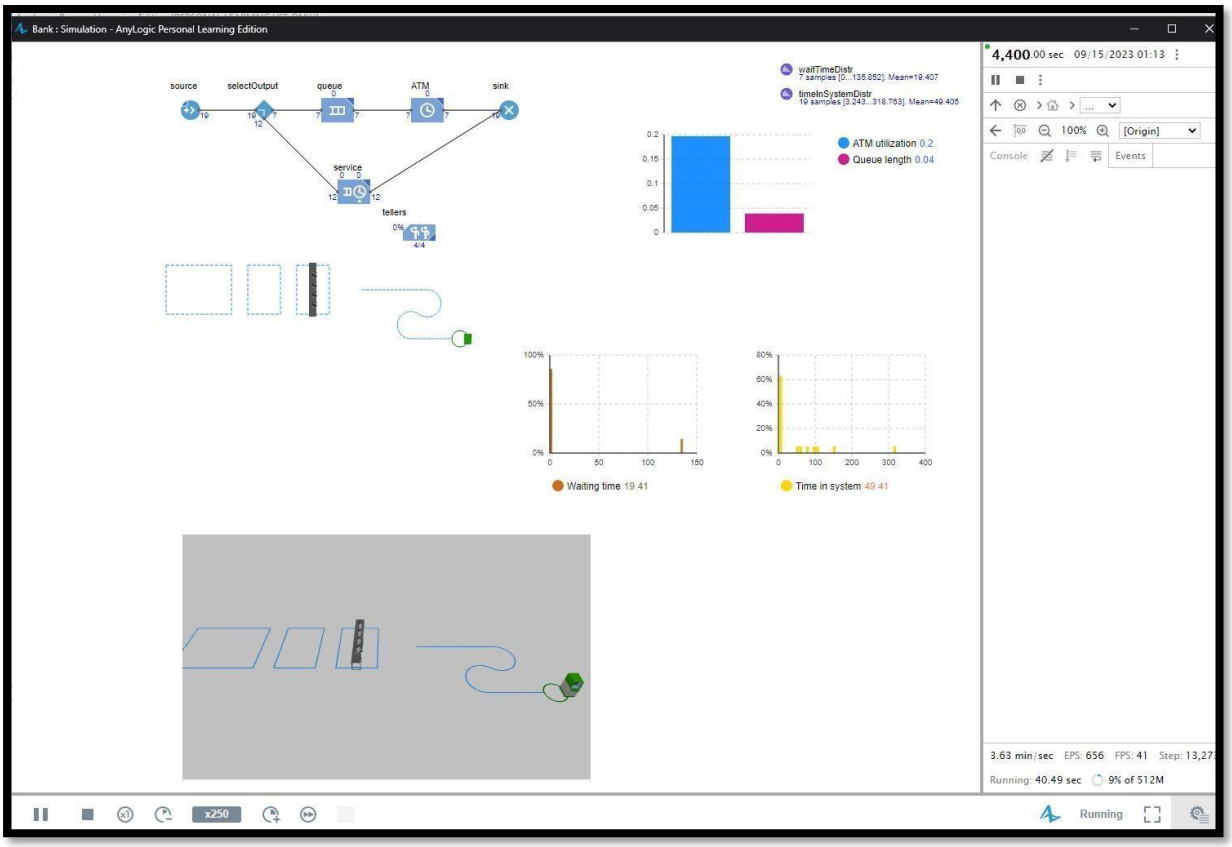

timeInSystemDistr - Histogram Data
Name:
timeInSystemDistr
Show name
Ignore
Visible:
yes
Value:
Number of intervals:
50
Calculate CDF
Calculate percentiles:
Low:
10
High:
10
Log to database
Turn on model execution logging
Values range
Automatically detected
Fixed
Initial interval size:
0.01
Data update
Update data automatically
waitTimeDistr
timeInSystemDistr


source
selectOutput
queue
ATM
sink
service
tellers
Agent
New agent:
Customer
Change dimensions:
Advanced
Actions
On before arrival:
On at exit:
On exit:
agent.enteredSystem = time();
Advanced
Description


connections
source
selectOutput
queue
ATM
sink
service
tellers
Advanced
Actions
On enter:
agent.startWaiting = time();
On at exit:
On exit:
waitTimeDistr.add(time() - agent.startWaiting);
On remove:
Advanced
Description


Customer
Main
Teller
source
selectOutput
queue
ATM
sink
service
tellers
Properties
sink - Sink
Name:
sink
Show name
Ignore
Actions
On enter:
timeInSystemDistr.add(time() - agent.enteredSystem);
Advanced
Description


Log in
Customer
Main
Teller
Properties
chart2 - Histogram
Name:
chart2
Ignore
Visible on upper agent
Lock
Show PDF
Show CDF
Show mean
Data
Title:
Time in system
Histogram:
timeInSystemDistr
PDF color:
gold
CDF color:
Mean color:
CDF & mean line Width:
Low % color:
High % color:
Add histogram data
Data update
Appearance
Position and size
Legend
Chart area
Advanced
Description
Waiting time
Time in system



Conclusion:

In this practical, we developed an agent-based model of an airport queuing system using AnyLogic software. By verifying and validating the model, we ensured that it accurately represents the real-world airport operations. The model allows us to analyse the efficiency of airport operations, including customer waiting times, queue lengths, and service utilization. Through this analysis, we can identify potential areas for improvement and optimize airport operations for better customer experiences.