G54SOD (Spring 2018)

Lecture 03

Discrete Event Modelling and Simulation

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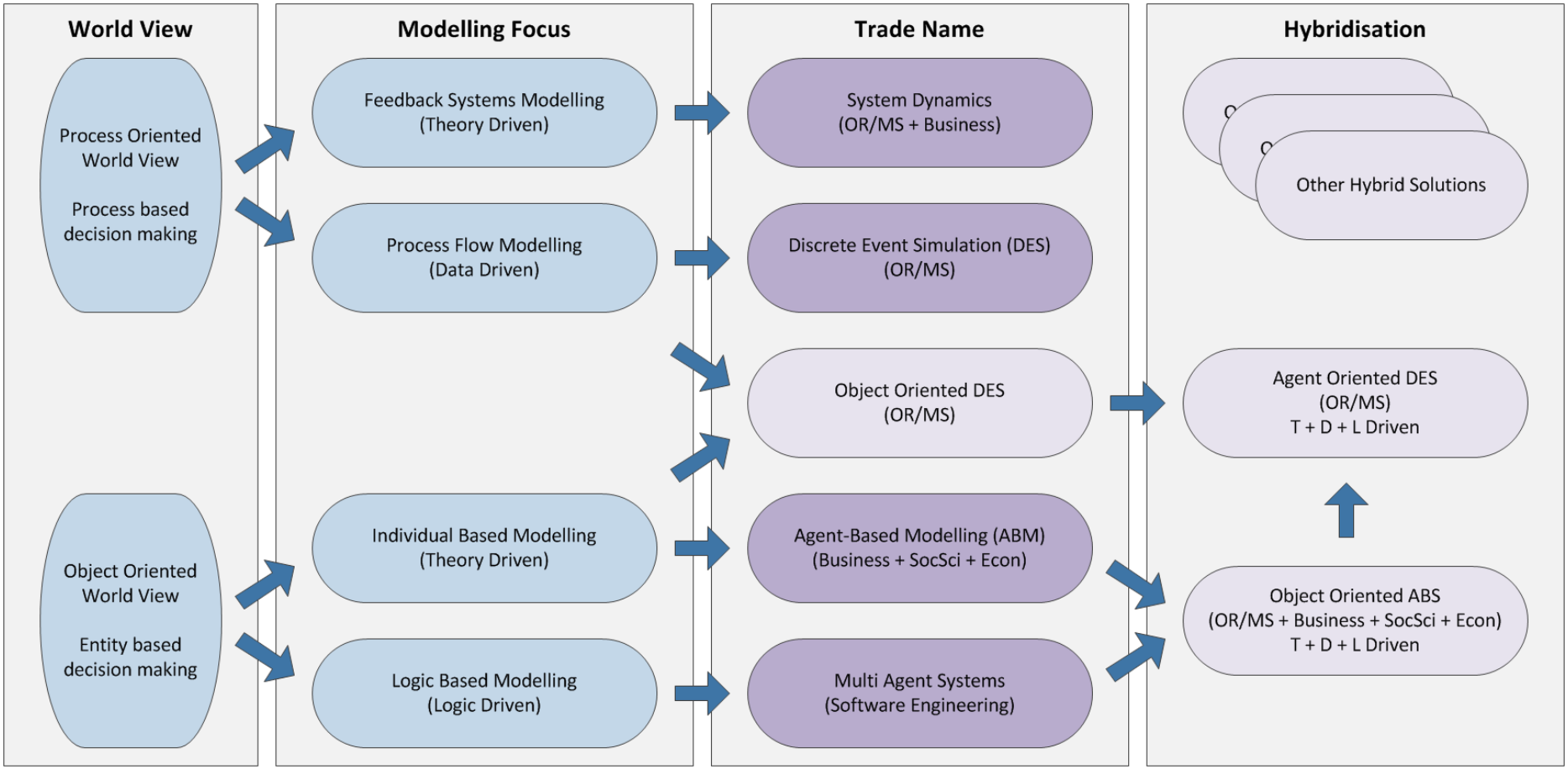
Motivation

- To introduce Discrete Event Modelling (DEM)
  - Looking at Activity Cycle Diagram
  - Looking at Process Flow Diagram
- To introduce Discrete Event Simulation (DES)
  - Three Phase Approach
  - Implementation in AnyLogic
  - Overcoming limitations of the PLE version
  - Application of DES in real world projects
- To present my PhD work

Simulation Modelling Framework



Theory Driven: Theories for model formulation; data for model validation
Data Driven: Data for model formulation (can be quantitative and qualitative); data for model validation
Logic Driven: Logic for model formulation; data for model validation

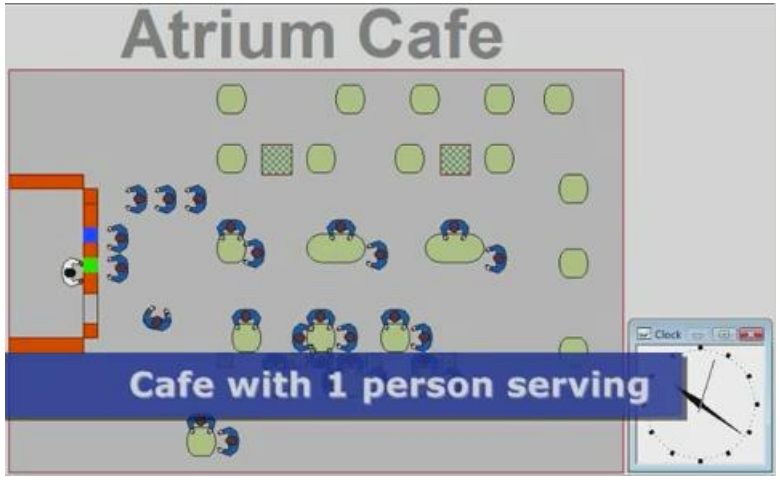
Simulation Modelling Framework

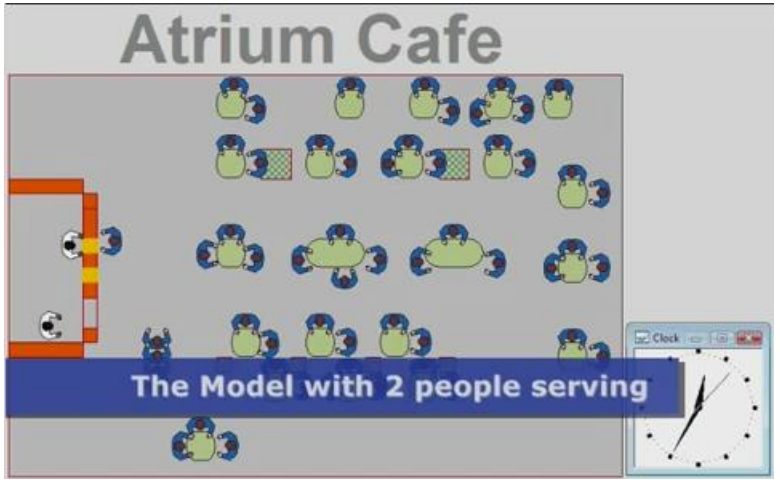
- Discrete Event Simulation (DES)
  - Study of queuing systems
  - Entities are routed through the system
  - Process: Organised in terms of queues and flows

- Object Oriented DES
  - Study of queuing systems
  - Entity templates defined as classes
  - Entities are passive object (they do not initiate any action)
  - Simple decisions can be made within the entities
  - Process: Organised in terms of queues and flows

Discrete Event Simulation Demo

- Coffee Shop Discrete Event Simulation Demo (Witness)



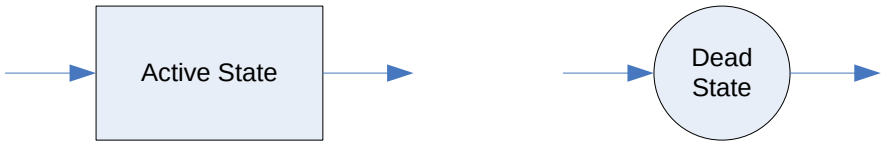


Discrete Event Modelling

- Terminology:
  - ***Entity***
    - A 'unit of traffic' within a model; entities trigger and respond to events; an ***event*** is an instantaneous happening that changes the state of the model
      - The arrival of an order (an event) might be simulated by bringing an entity into the system; the entity could have a state variable set to "not fulfilled"
  - ***Resource***
    - A system element that provides service; entities typically use resources; resources are usually capacity-limited, so entities compete for their use and sometimes must wait to use them (resulting in ***queueing***).
      - A resource can be an order-processing point, where items listed in the order are selected and boxed; this is represented by a time delay and a change to the order (setting its state variable to "fulfilled")
    - A resource can have several units of capacity

Discrete Event Modelling

- Terminology (cont.)
  - Over time entities co-operate and hence change state
    - Entity states:
      - ***Active state***: Involves the co-operation of different classes of entities; duration can be determined in advance, usually by taking a sample from an appropriate probability distribution if the simulation is stochastic
      - ***Dead state***: No co-operation, entity waits for something to happen; duration cannot be determined in advance



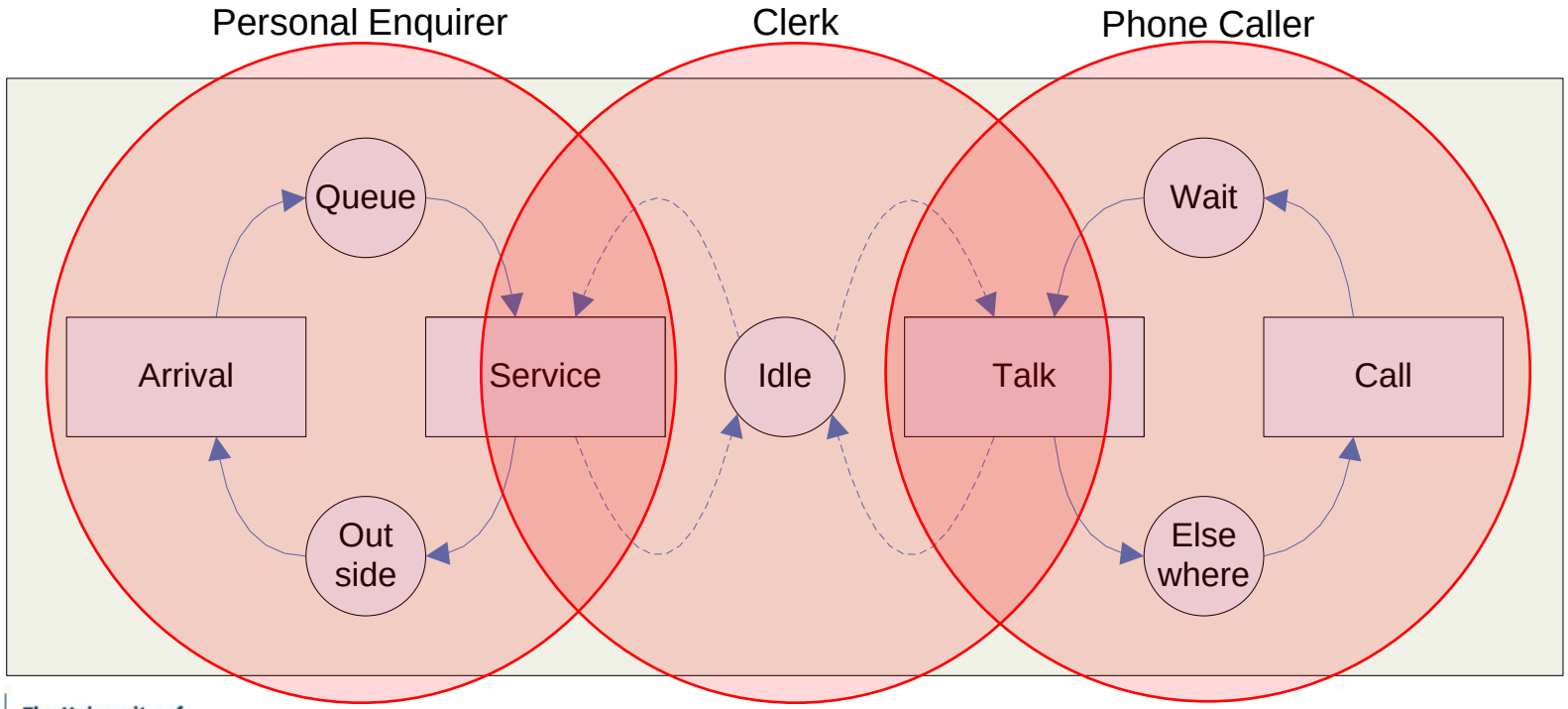
Discrete Event Modelling

- Hands-On Example [Pidd 1998]
  - Booking clerk at theatre:
    - A theatre booking clerk is employed to sell tickets and answer enquiries. Enquiries can come from someone at the box office or someone phoning the theatre.

    - Constraints
      - The clerk is instructed to give priority to the personal customers
      - Customer and phone calls queue on a FIFO basis
      - Phone callers never hang up

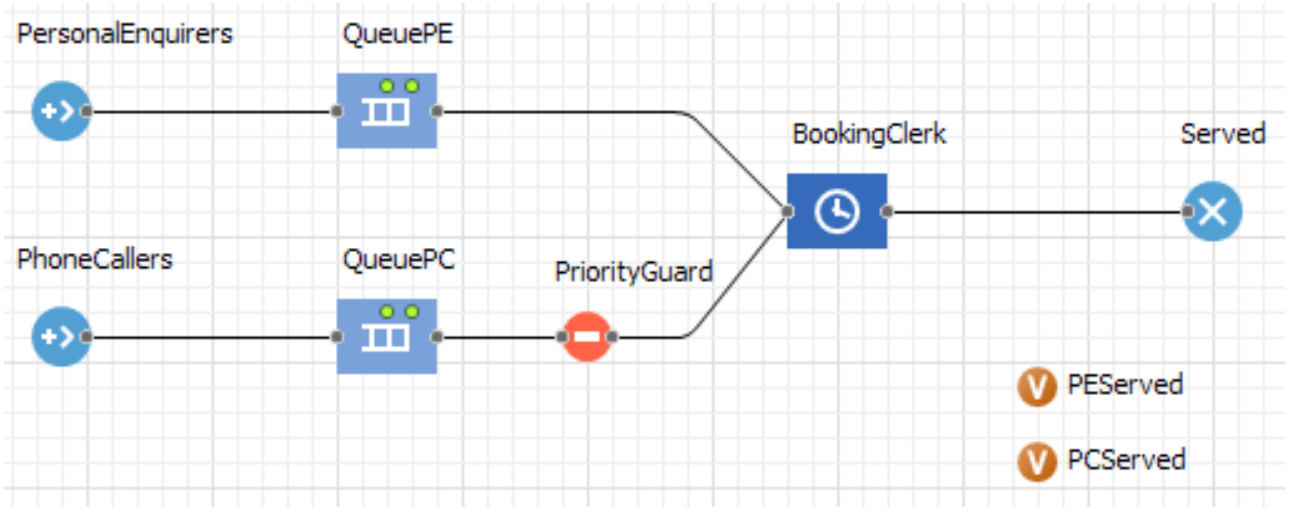
Discrete Event Modelling

- Hands-On Example (cont.)
  - Activity Cycle Diagram for ticket sales and enquiries (focuses on the states that the entities and resources are in)



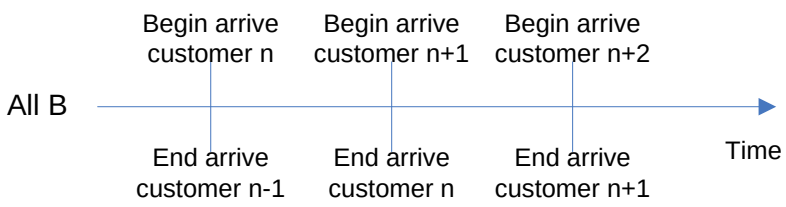
Discrete Event Modelling

- Hands-On Example (cont.)
  - Process Flow Diagram for ticket sales and enquiries (focuses on the flow of entities from the point where they enter the system until they leave the system)

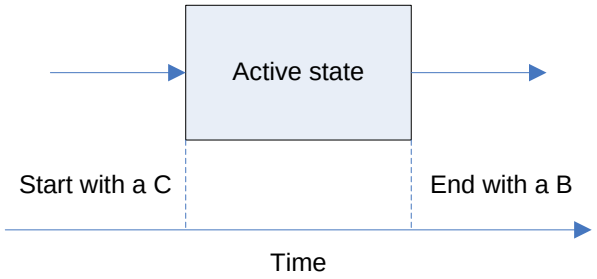


Discrete Event Simulation (DES)

- Three-Phase Approach (first described by Tocker in 1963)
  - In this simulation approach events are classified into two types
    - **B (bound or booked) Events:** State changes that are scheduled to occur at a point in time. In general B events relate to arrivals or the completion of an activity.
    - **C (conditional) Events:** State changes that are dependent on the conditions in the model. In general C events relate to the start of some activity



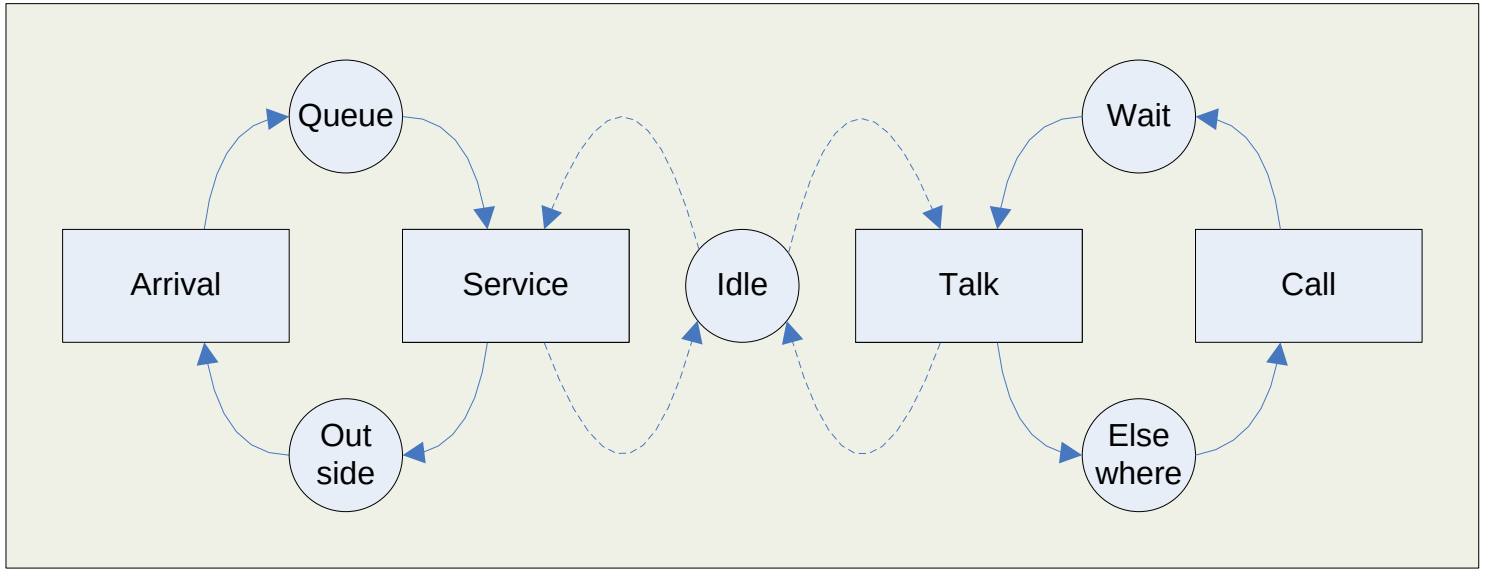
Arrival process



Activity

Discrete Event Simulation

- Three-Phase Approach
  - Activity Cycle Diagram for ticket sales and enquiries
    - B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk
    - C1: BeginService ... C2: BeginTalk



Discrete Event Simulation

- Three-Phase Approach
  - Process Flow Diagram for ticket sales and enquiries
    - B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk
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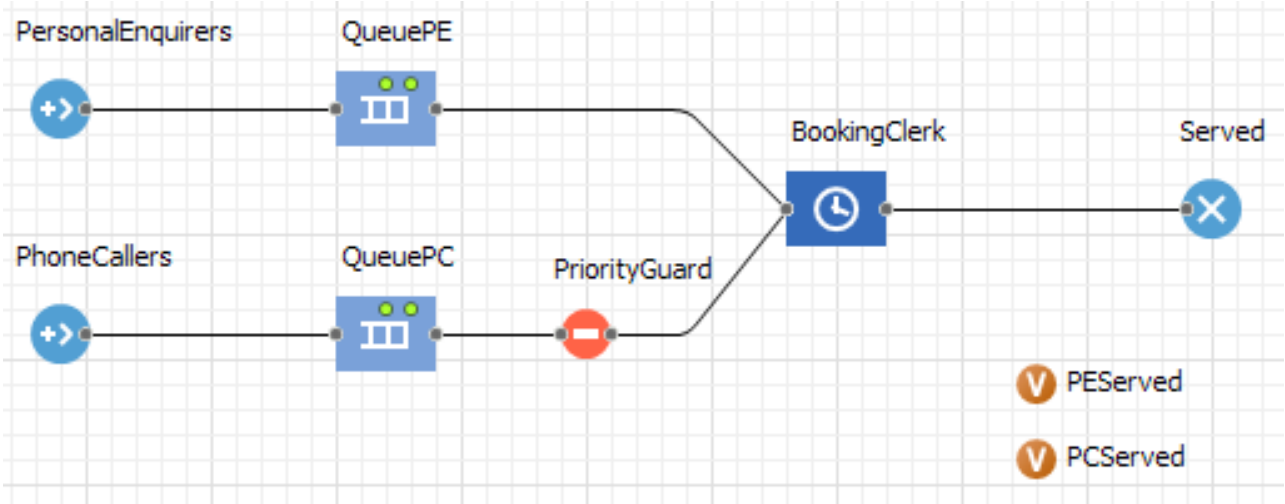
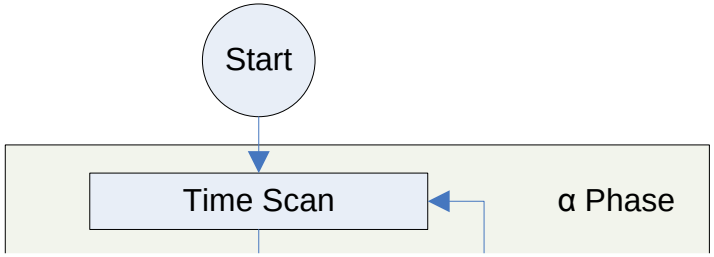


Discrete Event Simulation



- ***α***: Find out when the next event is due, move simulation clock to that time, put all entities due to engage in a B at that time into the *DueNow* list
- ***β***: Execute activities of entities in the *DueNow* list
- ***γ***: Executive must attempt each C in turn by checking if the condition in the test heads are satisfied

Discrete Event Simulation

- Required information about each entity
  - ***Time cell***: Time when entity is next due to change state, if this is known; only meaningful if entity is committed to some B in the future
  - ***Availability***: Boolean field showing whether the entity is committed to some B in the future
    - If **TRUE** entity is uncommitted and its time cell is meaningless
    - If **FALSE** time cell indicates when entity will next change state
  - ***Next activity***: Only meaningful if the availability is FALSE and it indicates the B in which the entity is due to engage at the time shown by the time cell

Discrete Event Simulation

- Three-Phase Approach
  - ***Initialisation***: Clerk is idle; first personal enquirer due to arrive at time 4 and first phone call due to arrive at time 6; time is 0; all queues are empty; no personal enquirers or phone calls have arrived
  - ***Random number stream***: 4,6,5,5,3,3,6,4,8

End of Init.: Clock=0; Queue=0; Wait=0; PersIn=0; PhoneIn=0; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	4	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	0	TRUE	

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - ***First α-Phase***: Find out when the next event is due, move simulation clock to that time, put all entities due to engage in a B at that time into the *DueNow* list (at t=4 entity 1 is due to arrive)
  - ***Random number stream***: 4,6,5,5,3,3,6,4,8

End of α: Clock=4; Queue=0; Wait=0; PersIn=0; PhoneIn=0; DueNow=1

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	4	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	0	TRUE	

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - ***First β-Phase***: Execute activities of entities in the *DueNow* list; remember that the service does not start in the β-Phase (brings first persEnq into the system and schedules next persEnq (to arrive 5 min later); entity is put in queue and counter for persEnq is increased)
  - ***Random number stream***: 4,6,5,5,3,3,6,4,8

End of β: Clock=4; Queue=1; Wait=0; PersIn=1; PhoneIn=0; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	0	TRUE	

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - ***First γ-Phase***: Executive must attempt each C in turn by checking if the condition in the test heads are satisfied (beginServ requires persEnq in queue and clerk to be idle; fulfilled; service takes 5 min)
  - ***Random number stream***: 4,6,5,5,3,3,6,4,8

End of γ: Clock=4; Queue=0; Wait=0; PersIn=1; PhoneIn=0; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - ***Second α-Phase***: Find out when the next event is due, move simulation clock to that time, put all entities due to engage in a B at that time into the *DueNow* list
  - ***Random number stream***: 4,6,5,5,3,3,6,4,8

End of α: Clock=6; Queue=0; Wait=0; PersIn=1; PhoneIn=0; DueNow=2

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	6	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - ***Second ß-Phase***: Execute activities of entities in the *DueNow* list; remember that the service does not start in the β-Phase
  - ***Random number stream***: 4,6,5,5,3,3,6,4,8

End of β: Clock=6; Queue=0; Wait=1; PersIn=1; PhoneIn=1; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	9	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - ***Second γ-Phase***: Executive must attempt each C in turn by checking if the condition in the test heads are satisfied
  - ***Random number stream***: 4,6,5,5,3,3,6,4,8

End of γ: Clock=6; Queue=0; Wait=1; PersIn=1; PhoneIn=1; DueNow=/

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	9	FALSE	Personal Arrival
(2) Phone call arrival machine	9	FALSE	Phone Call
(3) Clerk	9	FALSE	EndService

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach
  - Third Round?

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

Discrete Event Simulation

- Three-Phase Approach

End of α3: Clock=9; Queue= ; Wait= ; PersIn= ; PhoneIn= ; DueNow=1,2,3

Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine			Personal Arrival
(2) Phone call arrival machine			Phone Call
(3) Clerk			EndService

End of β3: Clock= ; Queue=1; Wait=2; PersIn=2; PhoneIn=2; DueNow=/

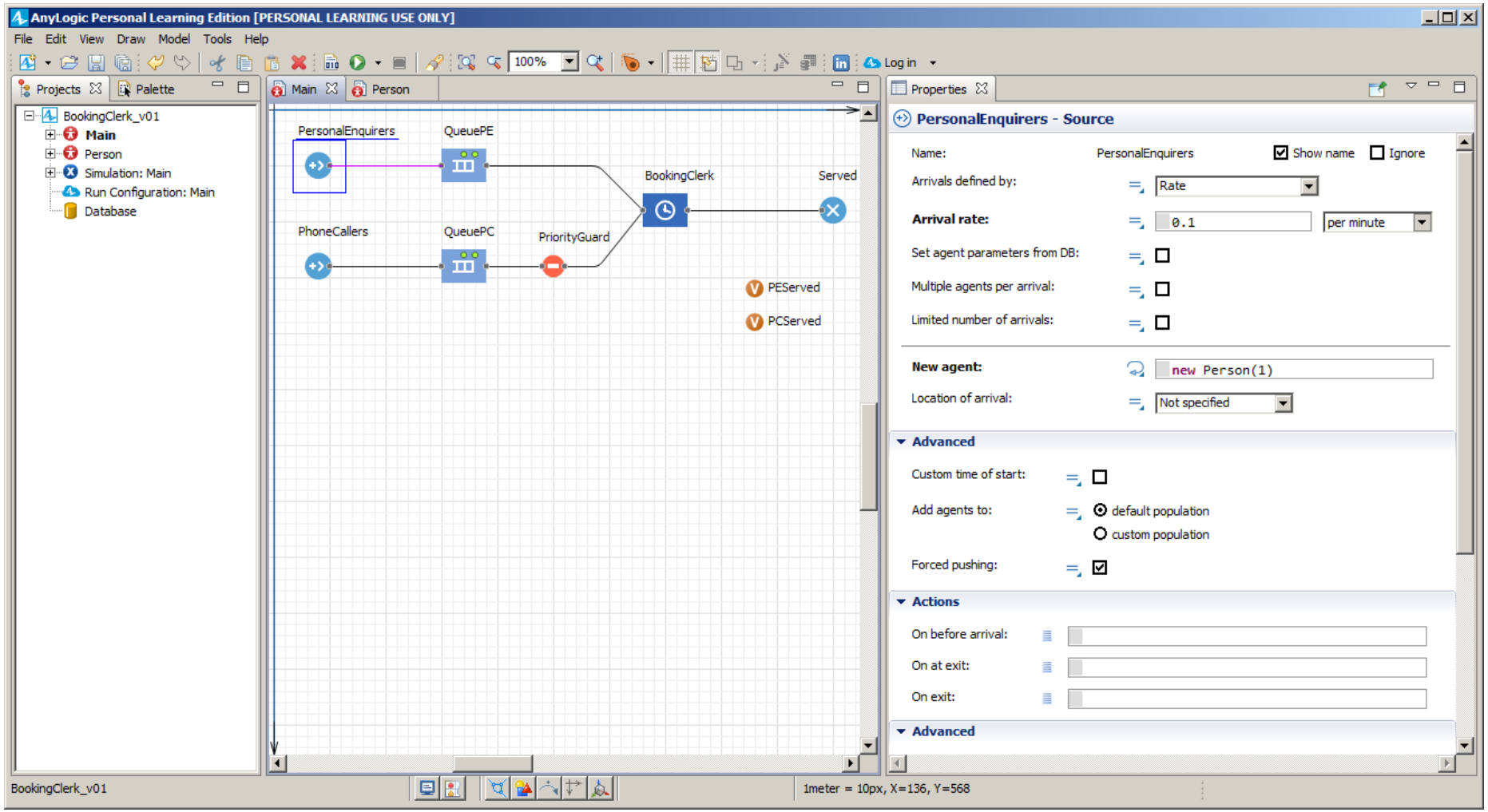
Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine	12		Personal Arrival
(2) Phone call arrival machine	15		Phone Call
(3) Clerk	9	TRUE	-

End of γ3: Clock= ; Queue=0; Wait=2; PersIn=2; PhoneIn=2; DueNow=/

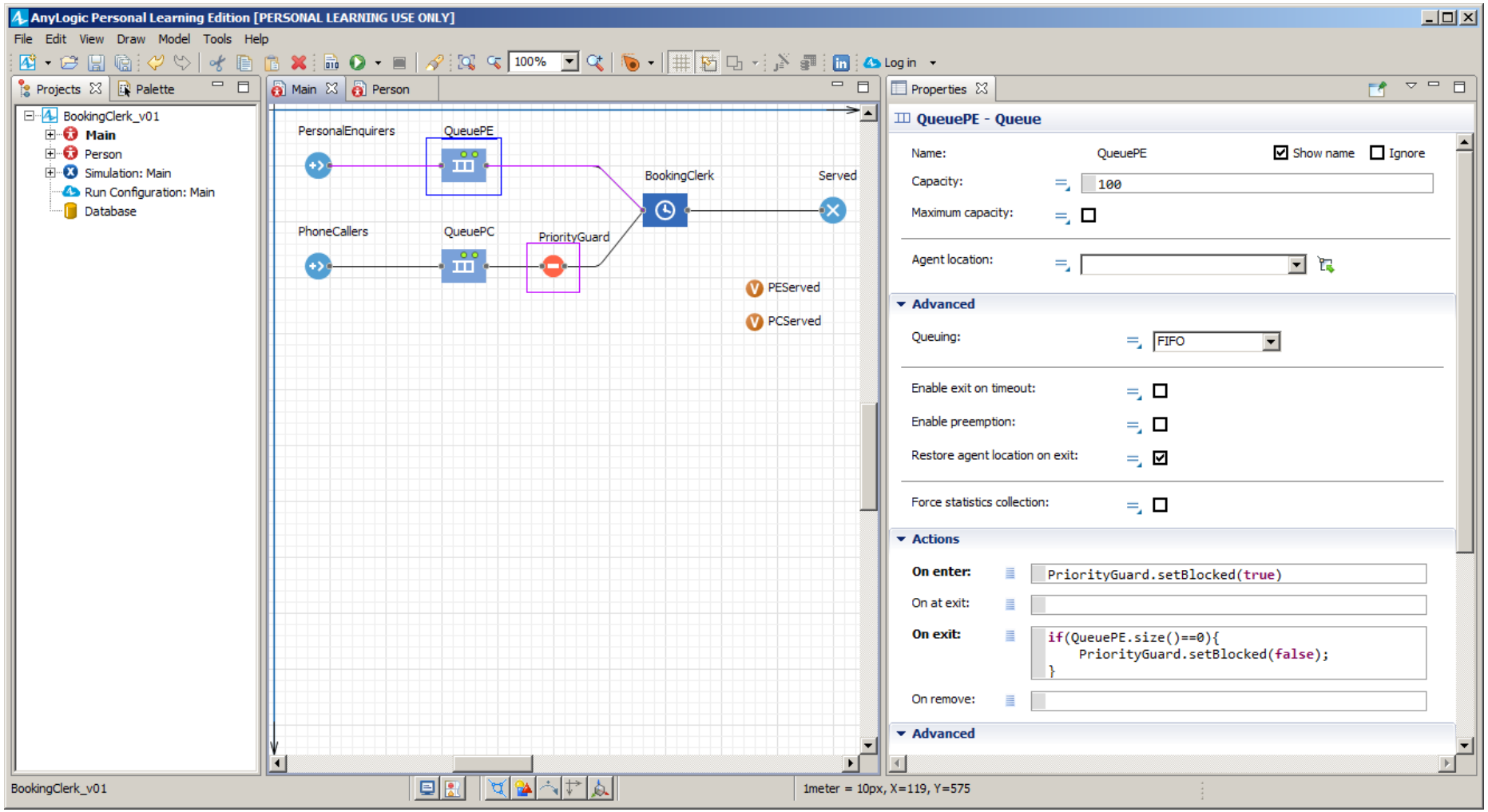
Entity	Time cell	Availability	Next Activity
(1) Personal enquirer arrival machine			Personal Arrival
(2) Phone call arrival machine			Phone Call
(3) Clerk	13	FALSE	EndService

B1: Arrive ... B2: EndOfService ... B3: Call ... B4: EndOfTalk ... C1: BeginService ... C2: BeginTalk

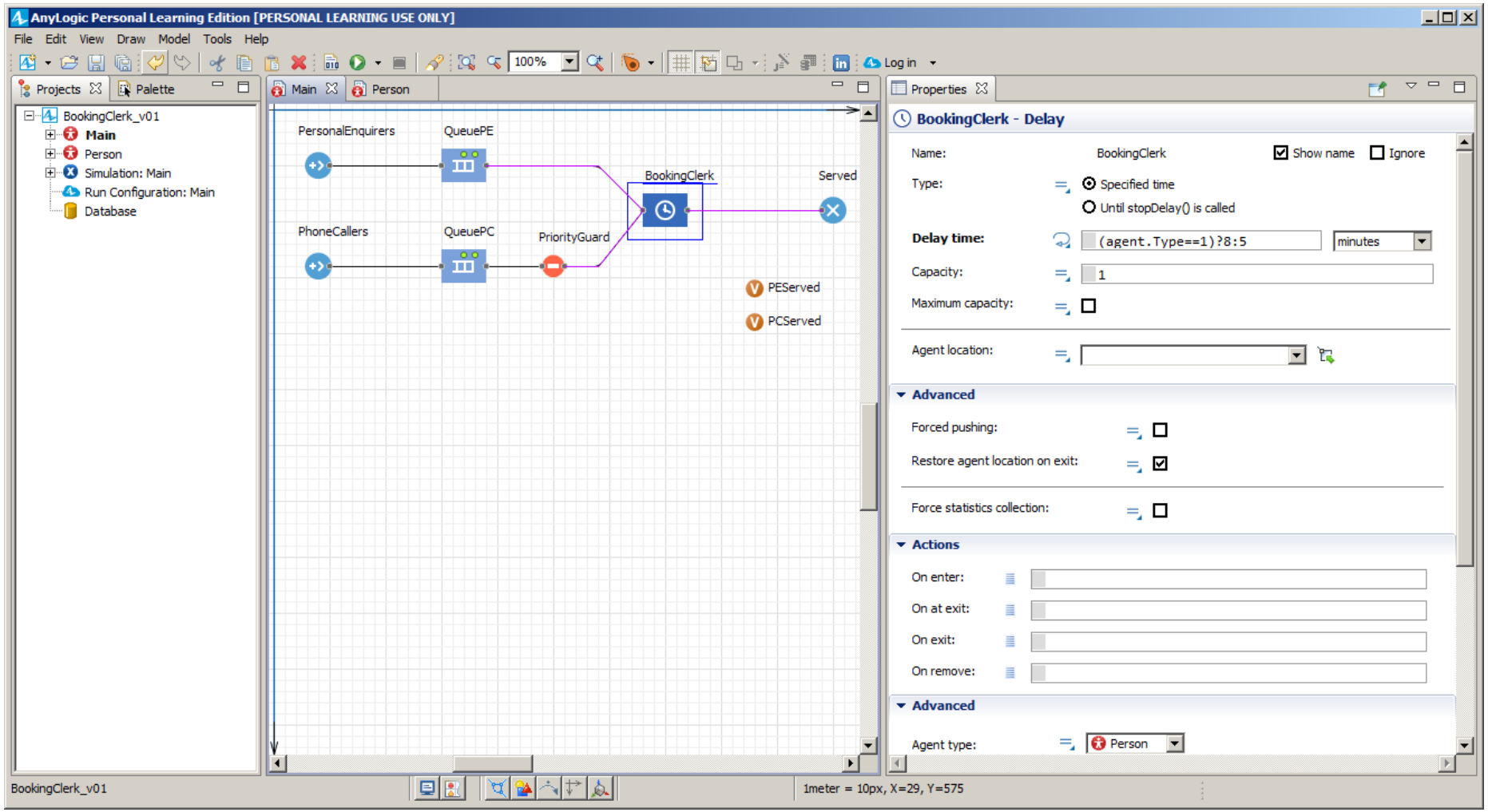
Discrete Event Simulation



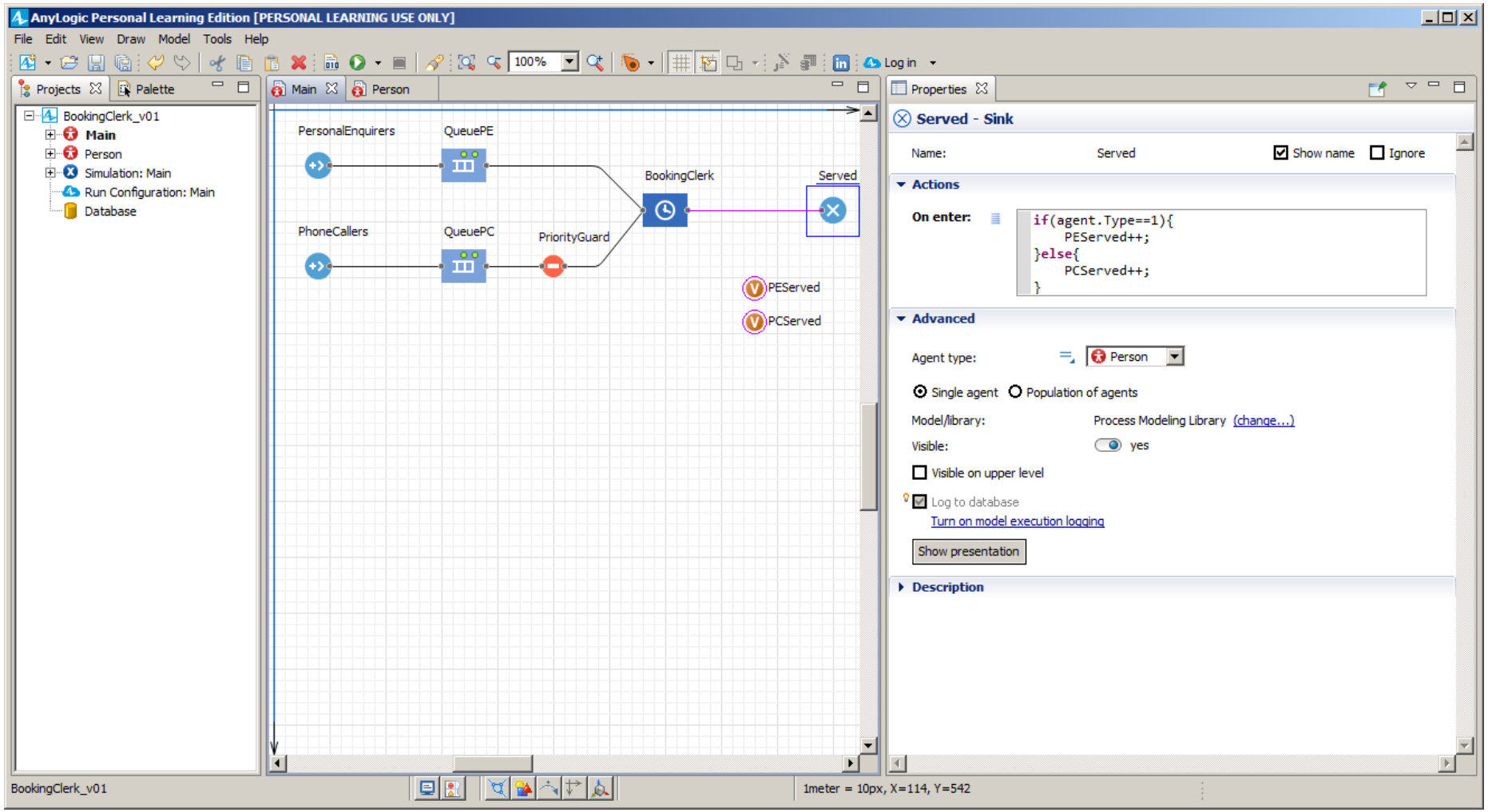
Discrete Event Simulation



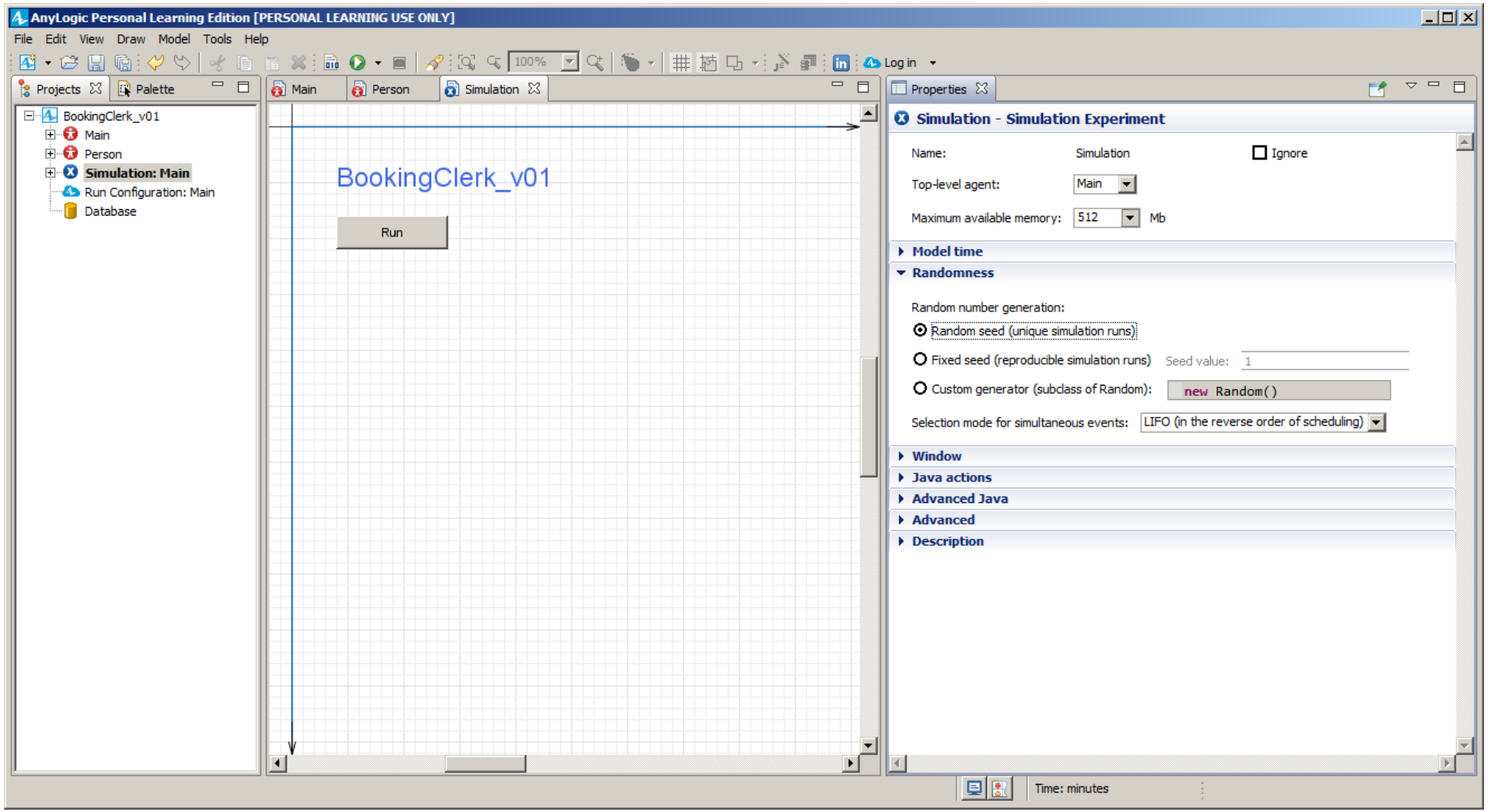
Discrete Event Simulation



Discrete Event Simulation



Discrete Event Simulation



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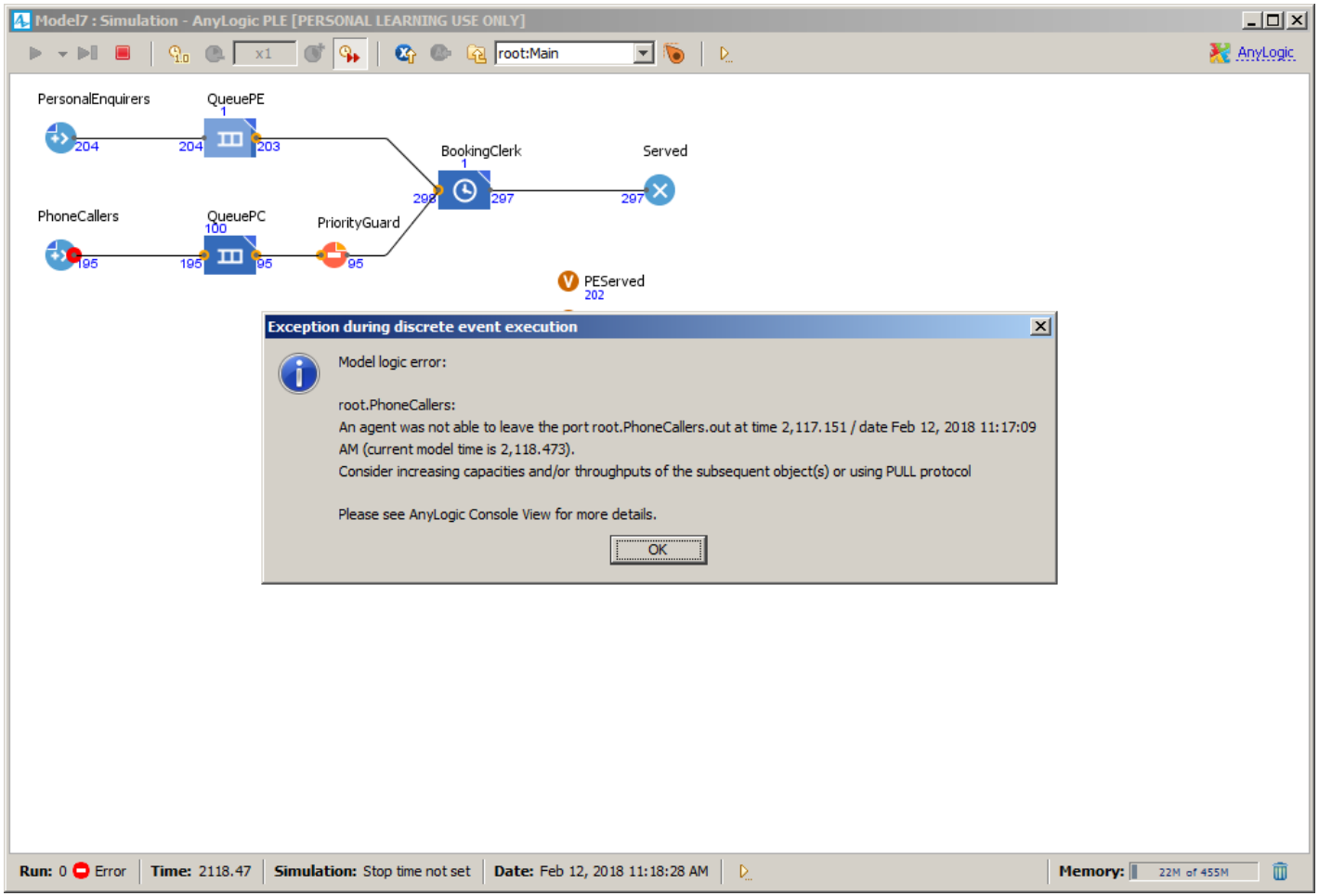

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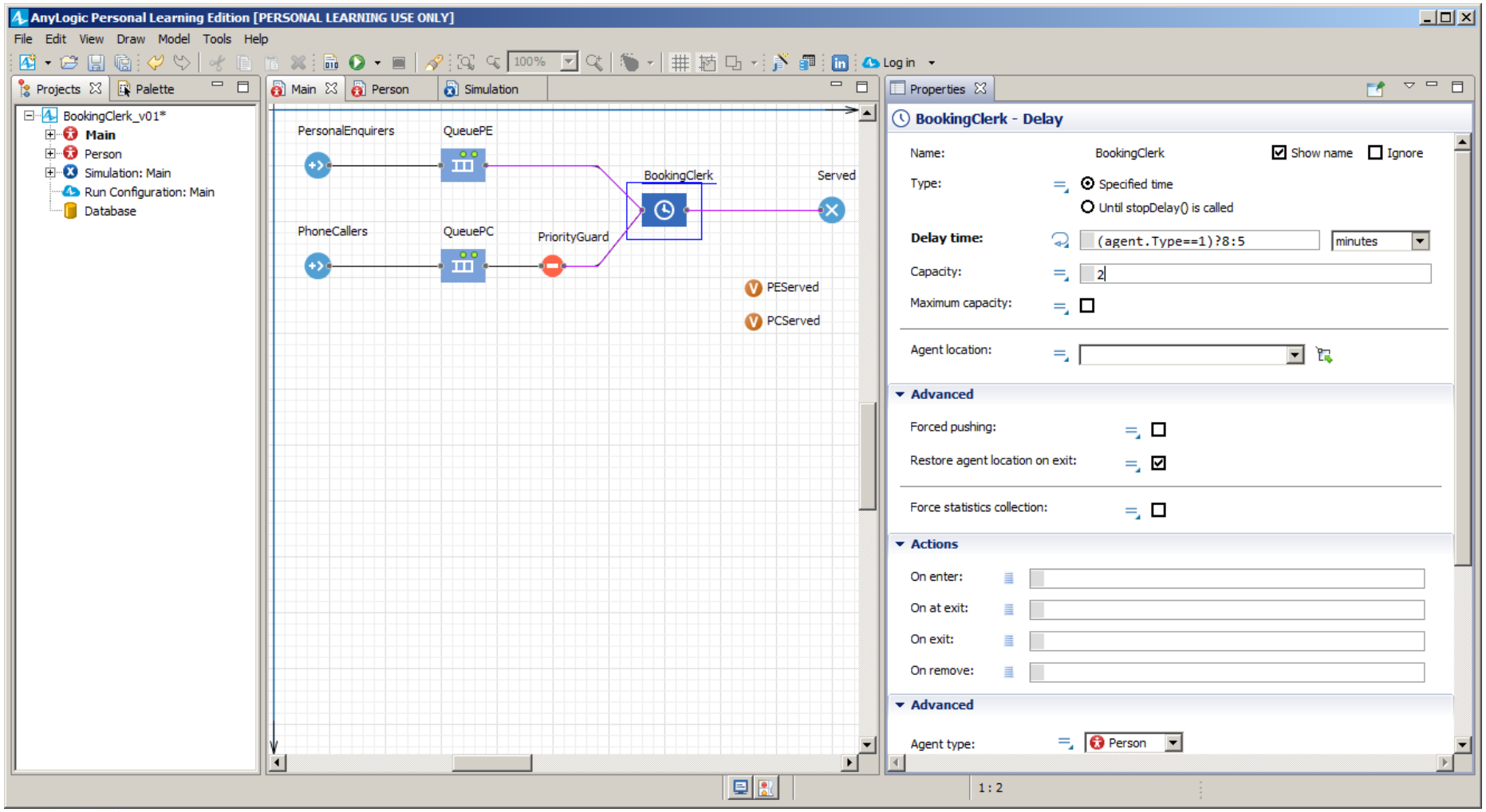

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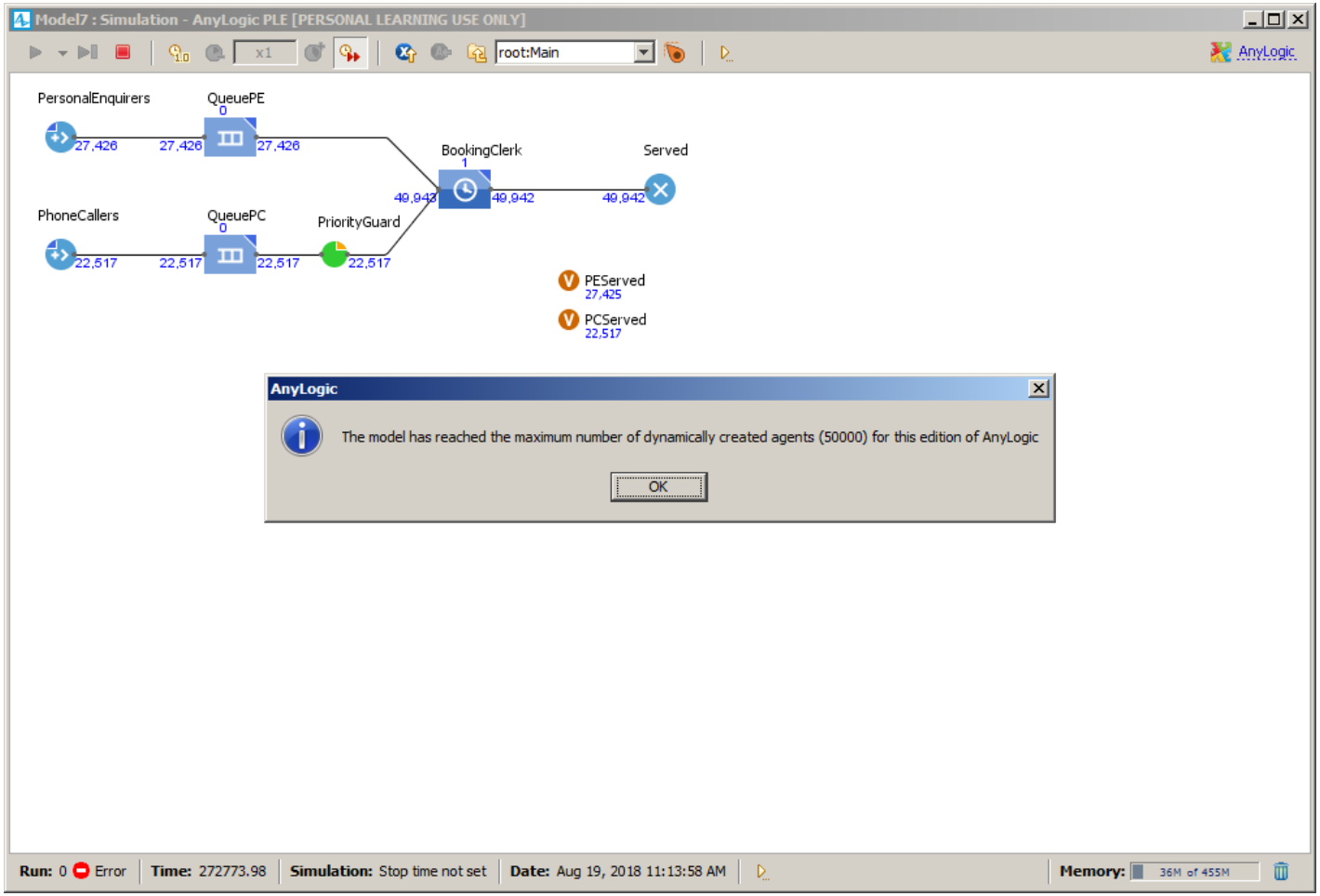
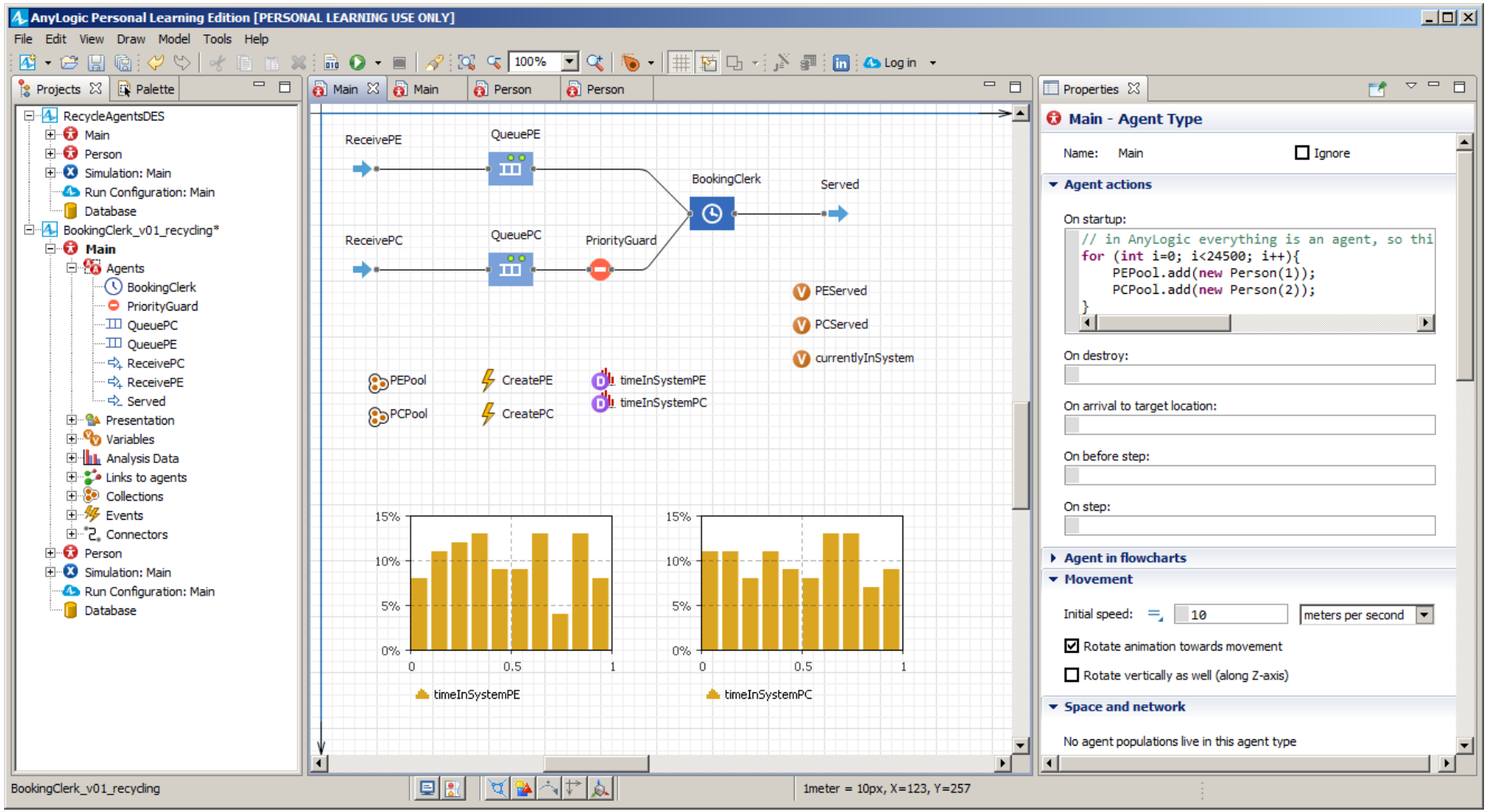


Discrete Event Simulation



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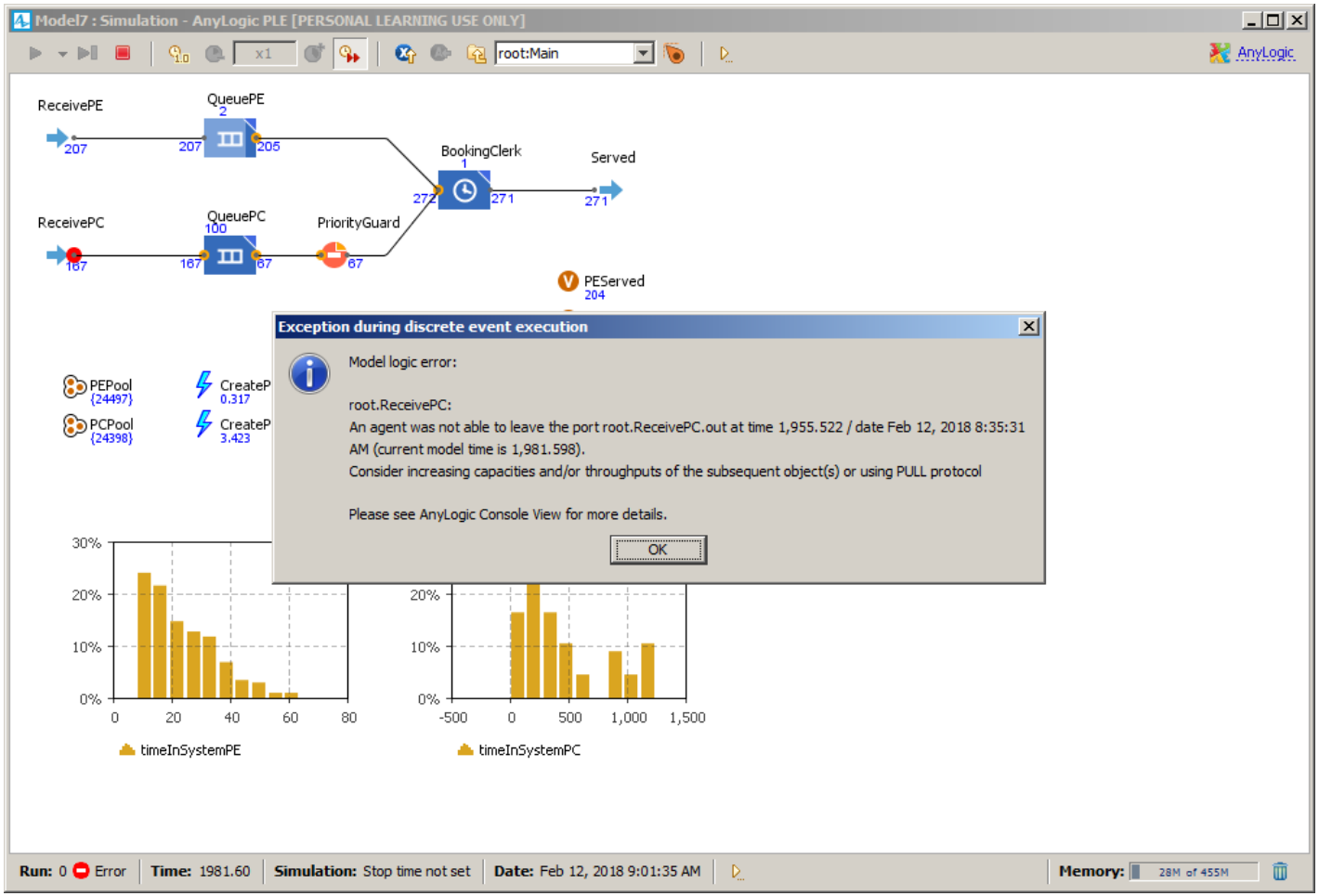
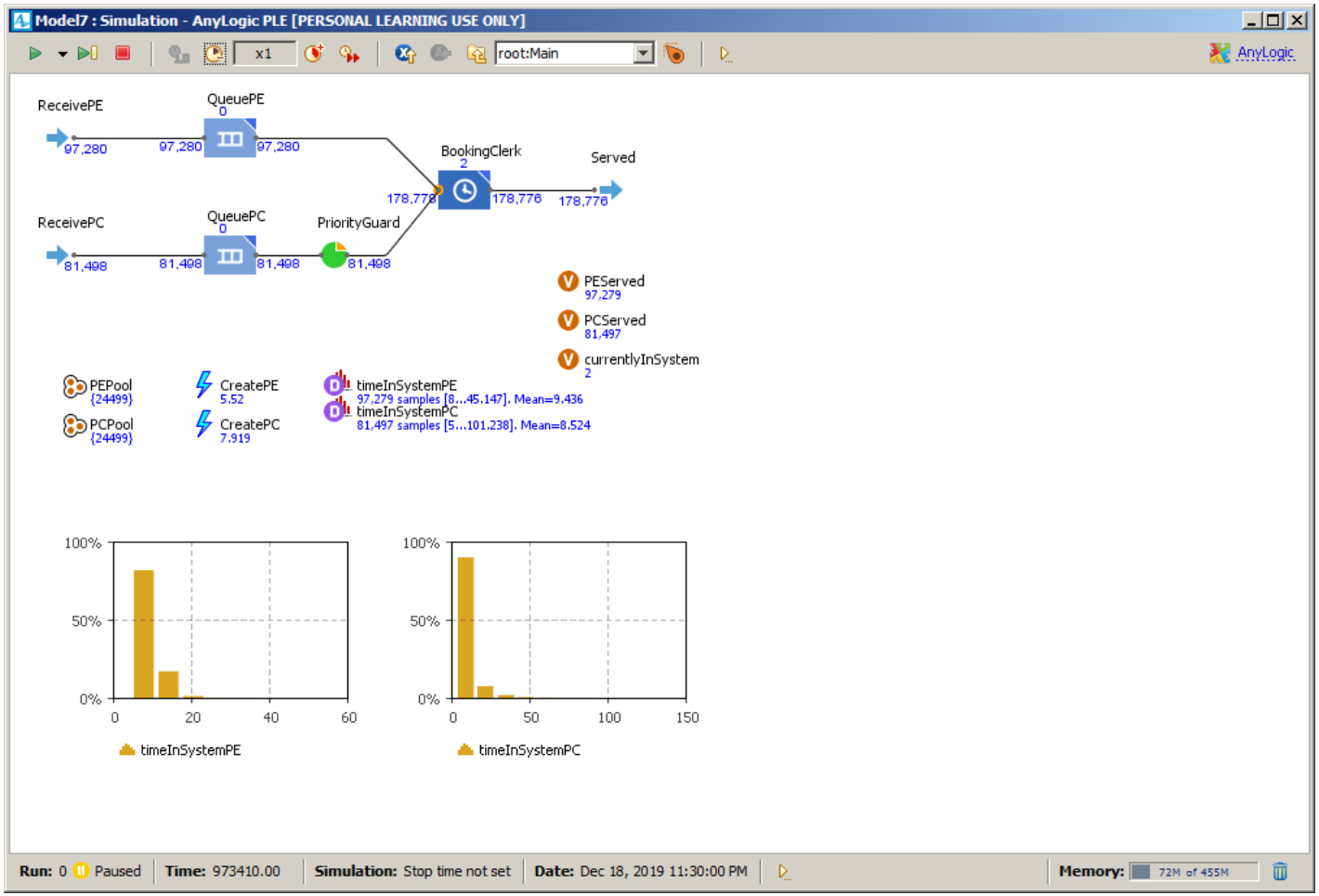
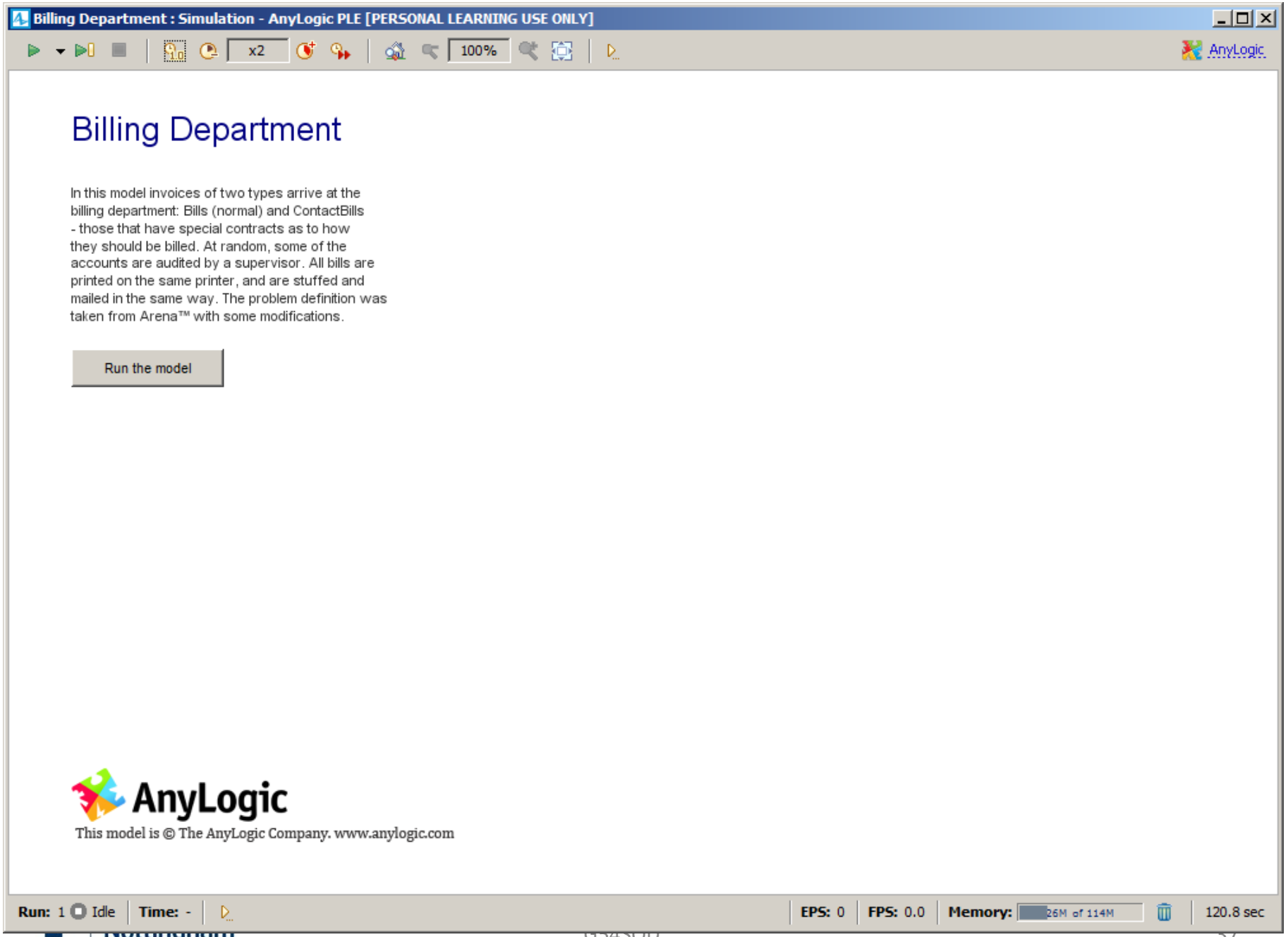
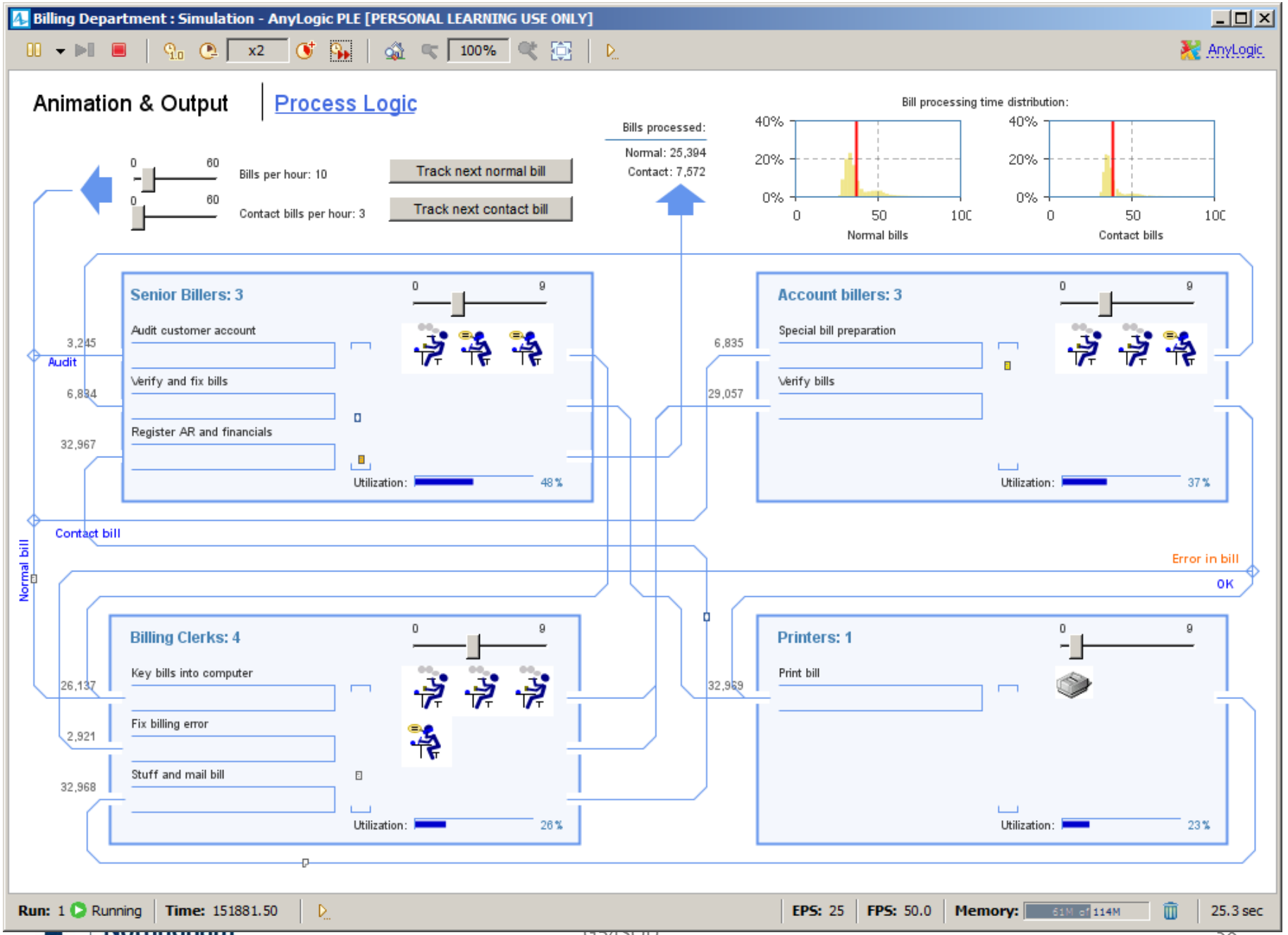


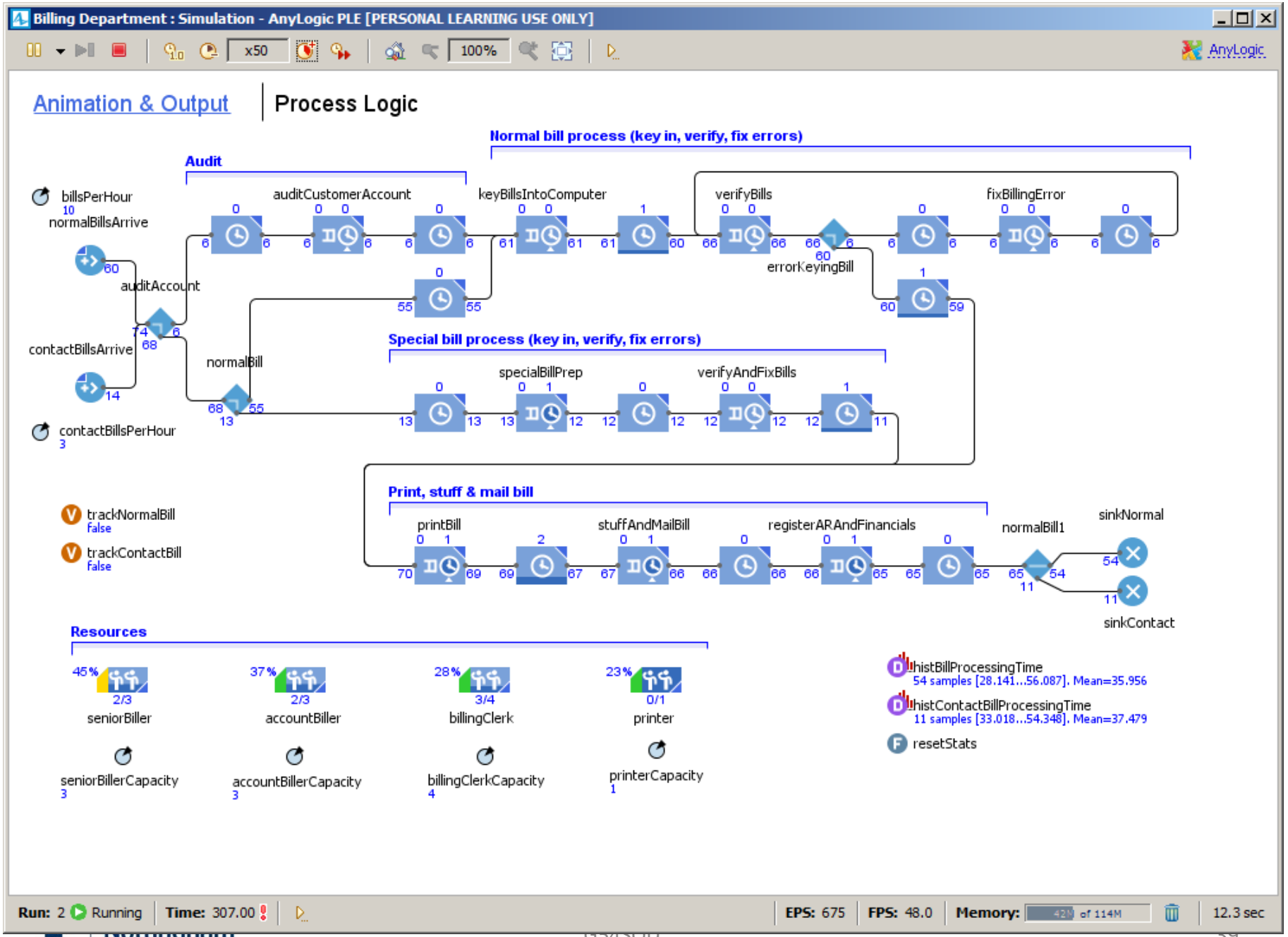
Discrete Event Simulation

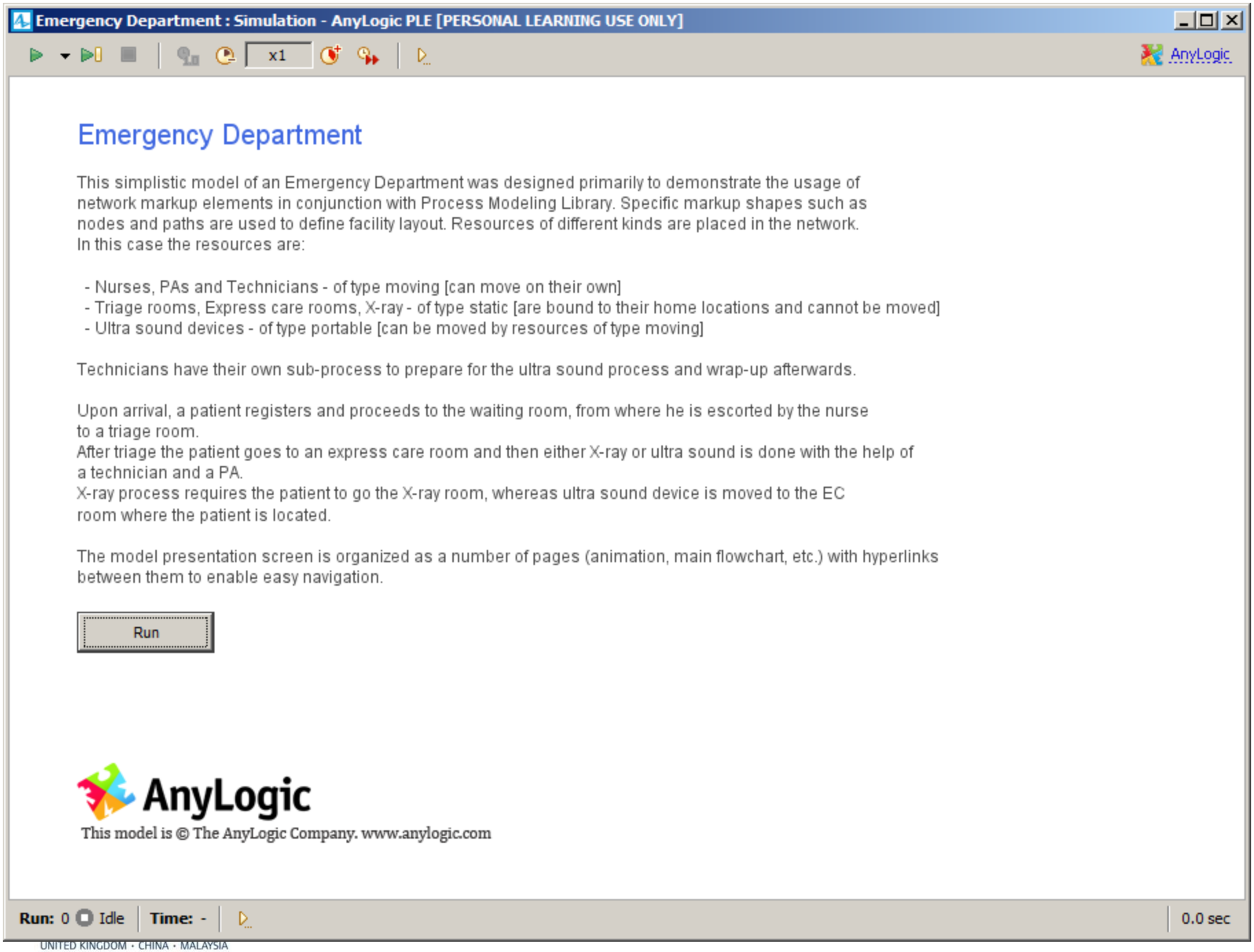


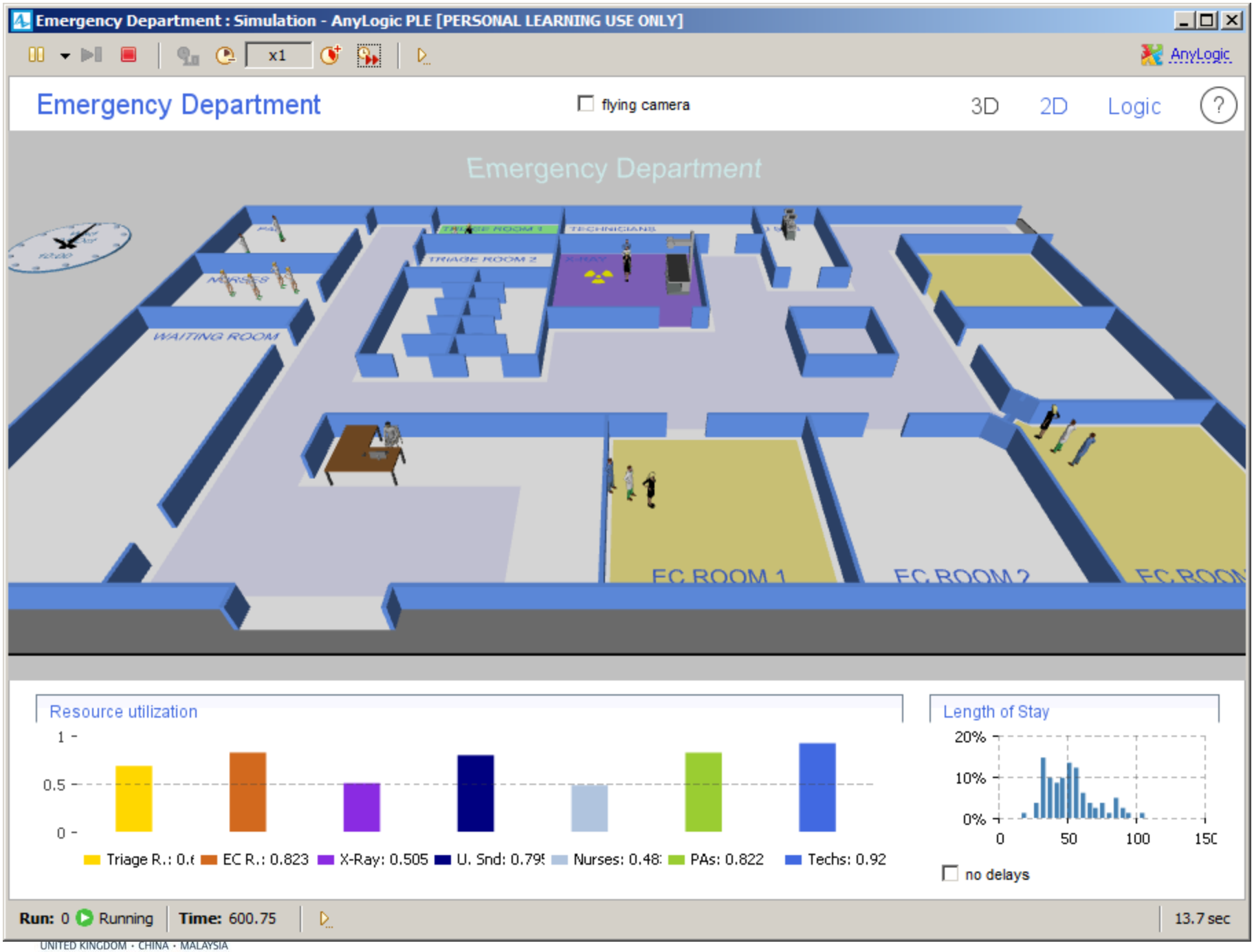
Discrete Event Simulation Examples


Billing Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x2
100%
AnyLogic
Billing Department
In this model invoices of two types arrive at the billing department: Bills (normal) and ContactBills - those that have special contracts as to how they should be billed. At random, some of the accounts are audited by a supervisor. All bills are printed on the same printer, and are stuffed and mailed in the same way. The problem definition was taken from Arena™ with some modifications.
Run the model
AnyLogic
This model is © The AnyLogic Company. www.anylogic.com
Run: 1 Idle
Time: -
EPS: 0
FPS: 0.0
Memory: 26M of 114M
120.8 sec


Billing Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x2
100%
AnyLogic
Animation & Output
Process Logic
Bills processed:
Normal: 25,394
Contact: 7,572
Bill processing time distribution:
40%
20%
0%
0
50
100
Normal bills
Contact bills
0
60
Bills per hour: 10
Contact bills per hour: 3
Track next normal bill
Track next contact bill
Senior Billers: 3
Audit customer account
Verify and fix bills
Register AR and financials
Utilization: 48%
Account billers: 3
Special bill preparation
Verify bills
Utilization: 37%
3,245
Audit
6,884
32,967
6,835
29,057
Contact bill
Normal bill
Error in bill
OK
Billing Clerks: 4
Key bills into computer
Fix billing error
Stuff and mail bill
Utilization: 26%
Printers: 1
Print bill
Utilization: 23%
26,137
2,921
32,968
32,969
Run: 1 Running
Time: 151881.50
EPS: 25
FPS: 50.0
Memory:
25.3 sec


Billing Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x50
100%
AnyLogic
Animation & Output
Process Logic
Normal bill process (key in, verify, fix errors)
Audit
billsPerHour
10
normalBillsArrive
auditCustomerAccount
keyBillsIntoComputer
verifyBills
fixBillingError
errorKeyingBill
auditAccount
contactBillsArrive
14
normalBill
Special bill process (key in, verify, fix errors)
specialBillPrep
verifyAndFixBills
contactBillsPerHour
3
trackNormalBill
false
trackContactBill
false
Print, stuff & mail bill
printBill
stuffAndMailBill
registerARAndFinancials
normalBill1
sinkNormal
sinkContact
Resources
45%
2/3
seniorBiller
37%
2/3
accountBiller
28%
3/4
billingClerk
23%
0/1
printer
seniorBillerCapacity
3
accountBillerCapacity
3
billingClerkCapacity
4
printerCapacity
1
histBillProcessingTime
54 samples [28.141...56.087], Mean=35.956
histContactBillProcessingTime
11 samples [33.018...54.348], Mean=37.479
resetStats
Run: 2 Running
Time: 307.00
EPS: 675
FPS: 48.0
Memory:
12.3 sec




Emergency Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x1
AnyLogic
Emergency Department
flying camera
3D
2D
Logic
Emergency Department
WAITING ROOM
TRIAGE ROOM 2
TECHNICIANS
X-RAY
EC ROOM 1
EC ROOM 2
Resource utilization
1
0.5
0
Triage R.: 0.6
EC R.: 0.823
X-Ray: 0.505
U. Snd: 0.795
Nurses: 0.48
PAs: 0.822
Techs: 0.92
Length of Stay
20%
10%
0%
0
50
100
150
no delays
Run: 0 Running
Time: 600.75
13.7 sec
UNITED KINGDOM · CHINA · MALAYSIA

Emergency Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]

x1

AnyLogic

Emergency Department

3D 2D Logic

Parameters

Nurses

1 2 3 4 5 6

PAs

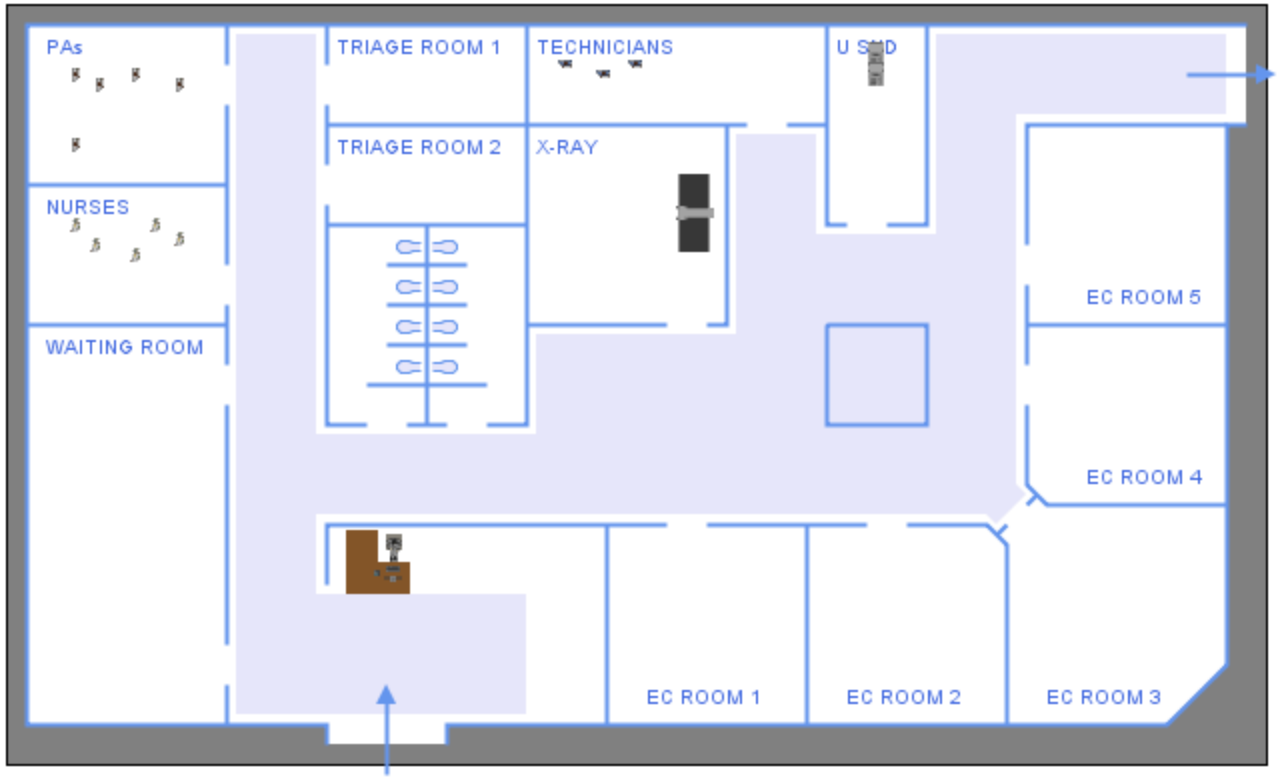
1 2 3 4 5 6

Technicians

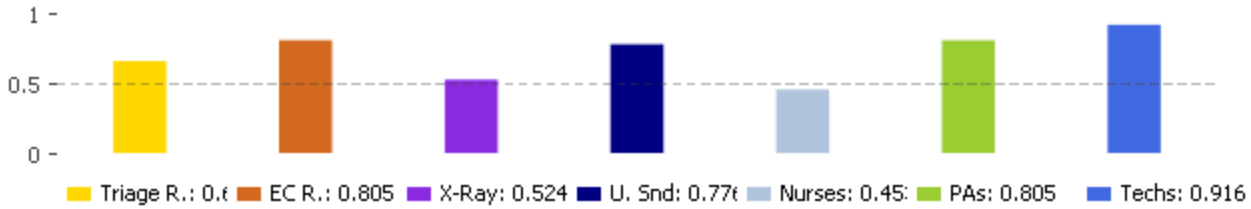
1 2 3 4 5 6

U-Sound devices

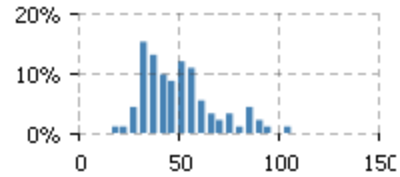
1 2 3 4 5 6



Resource utilization



Length of Stay



no delays

Run: 0 Running | Time: 664.25 | 75.7 sec

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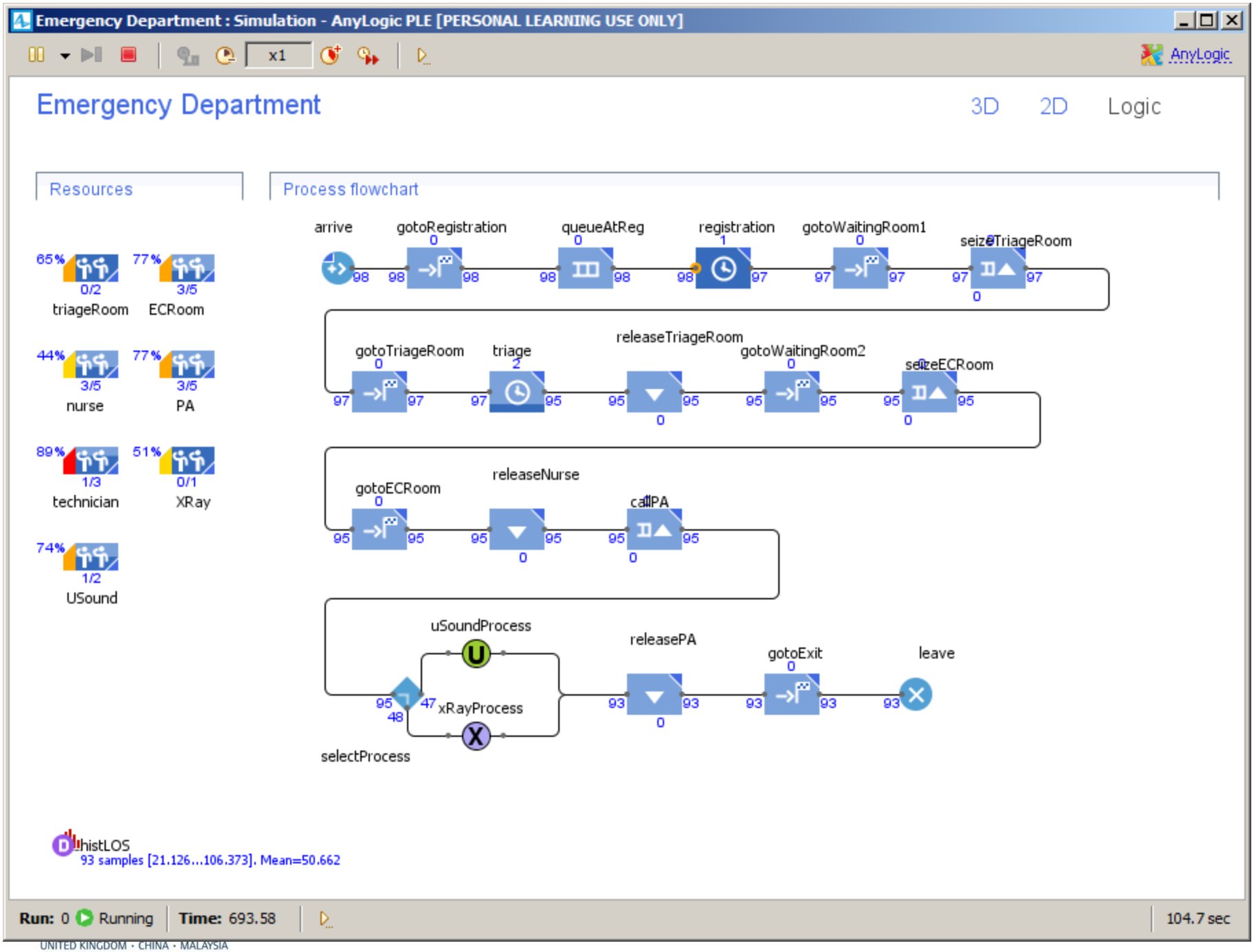
Emergency Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x1
AnyLogic
Emergency Department
3D
2D
Logic
Resources
Process flowchart
65%
0/2
triageRoom
77%
3/5
ECRoom
44%
3/5
nurse
77%
3/5
PA
89%
1/3
technician
51%
0/1
XRay
74%
1/2
USound
arrive
gotoRegistration
queueAtReg
registration
gotoWaitingRoom1
seizeTriageRoom
releaseTriageRoom
gotoTriageRoom
triage
gotoWaitingRoom2
seizeECRoom
releaseNurse
gotoECRoom
callPA
uSoundProcess
releasePA
gotoExit
leave
xRayProcess
selectProcess
histLOS
93 samples [21.126...106.373]. Mean=50.662
Run: 0 Running
Time: 693.58
104.7 sec
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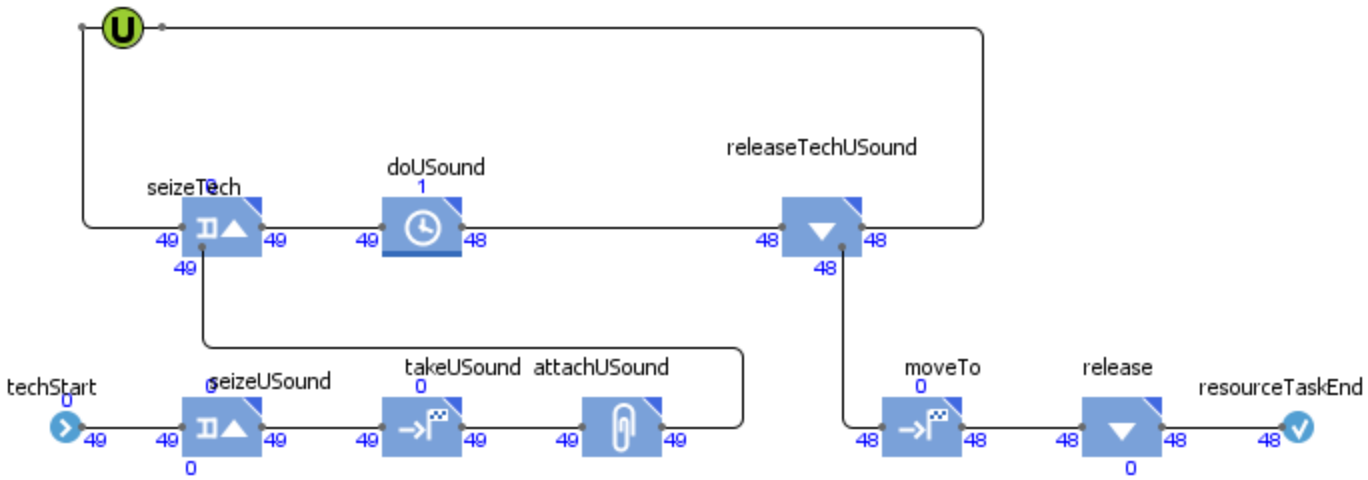
Emergency Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]

x1

AnyLogic

Back | Ultra Sound Process



technician
root.technician: ResourcePoolAll units: 3Active: 316 : 16[technician].ResourceUnitEntityServiceSubtask:root.xRayProcess.callTech:root.<Default Population>[25]17 : 17[technician].ResourceUnitEntit

usound
root.USound: ResourcePoolAll units: 2Active: 28 : 8[USound].ResourceUnitEntityServiceSubtask:root.uSoundProcess.seizeUSound:root.<Default Population>[16]Idle units: 1...

Run: 0 Running | Time: 729.70

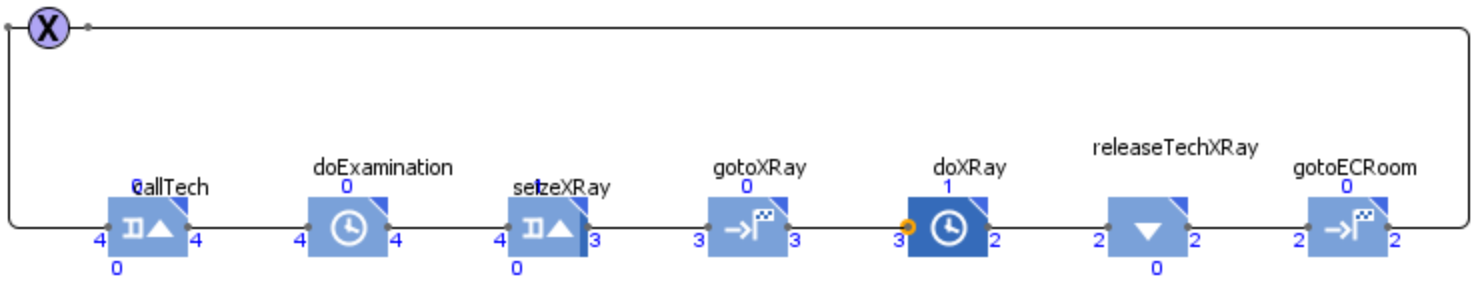
140.7 sec

Emergency Department : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]

x5

AnyLogic

Back | X-Ray Process



technician
root.technician: ResourcePoolAll units: 3Active: 316 : 16[technician].ResourceUnitEntityServiceSubtask:root.xRayProcess.callTech:root.<Default Population>[24]17 : 17[technician].Resourc

xray
root.XRay: ResourcePoolAll units: 1Active: 115 : 15[XRay].ResourceUnitEntityServiceSubtask:root.xRayProcess.seizeXRay:root.<Default Population>[25]Idle units: 0...

Run: 0 Running | Time: 52.25 | 34.1 sec

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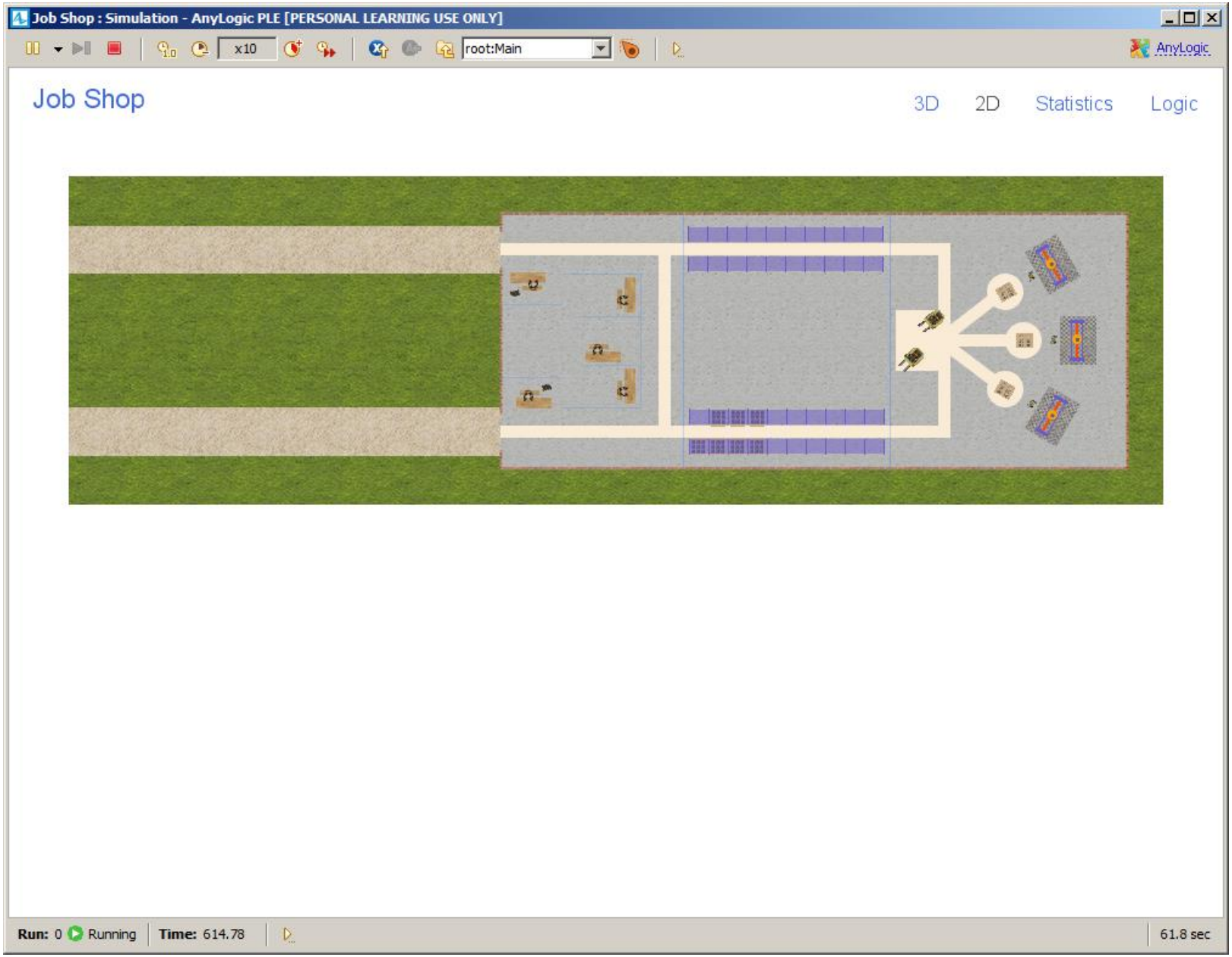
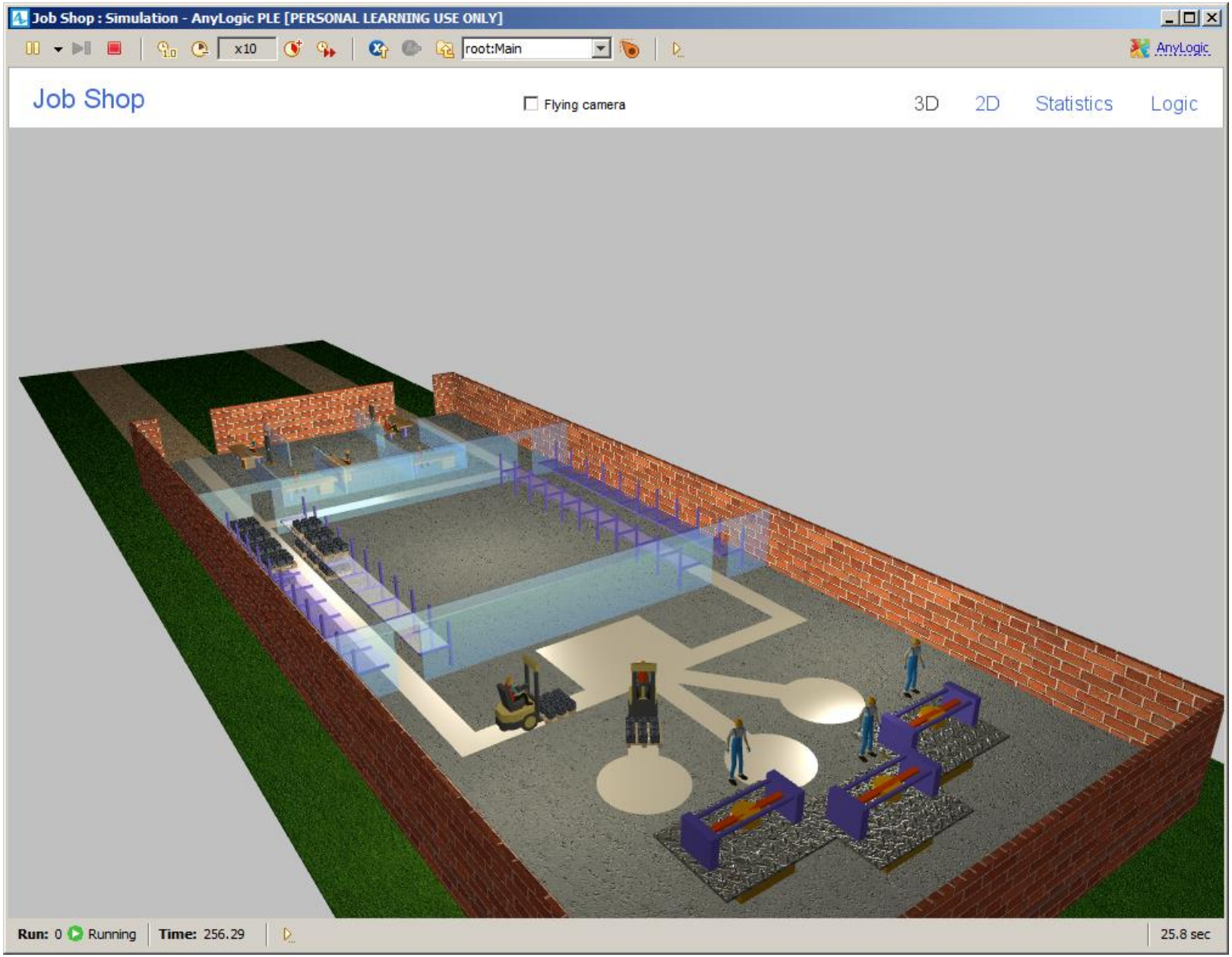
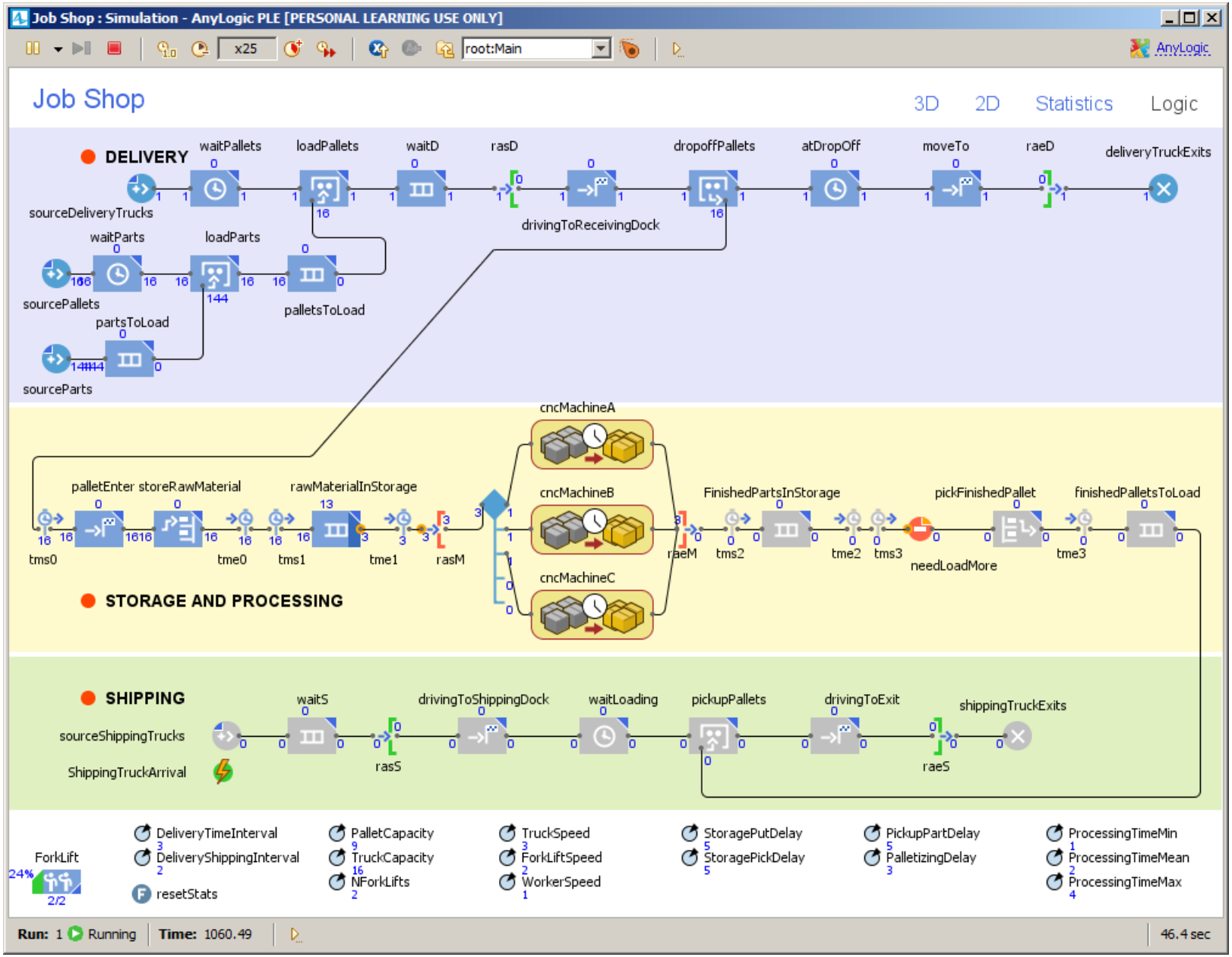
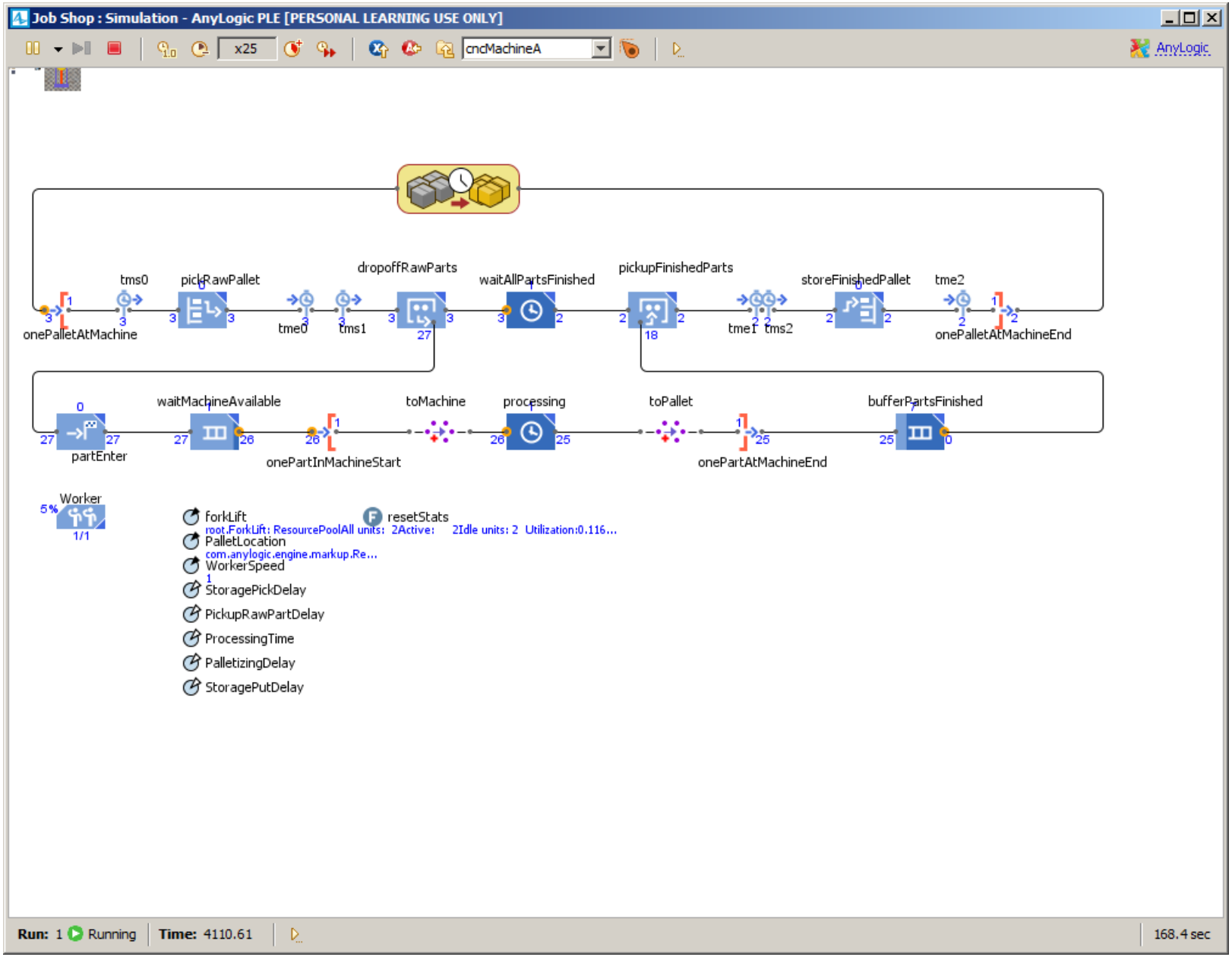
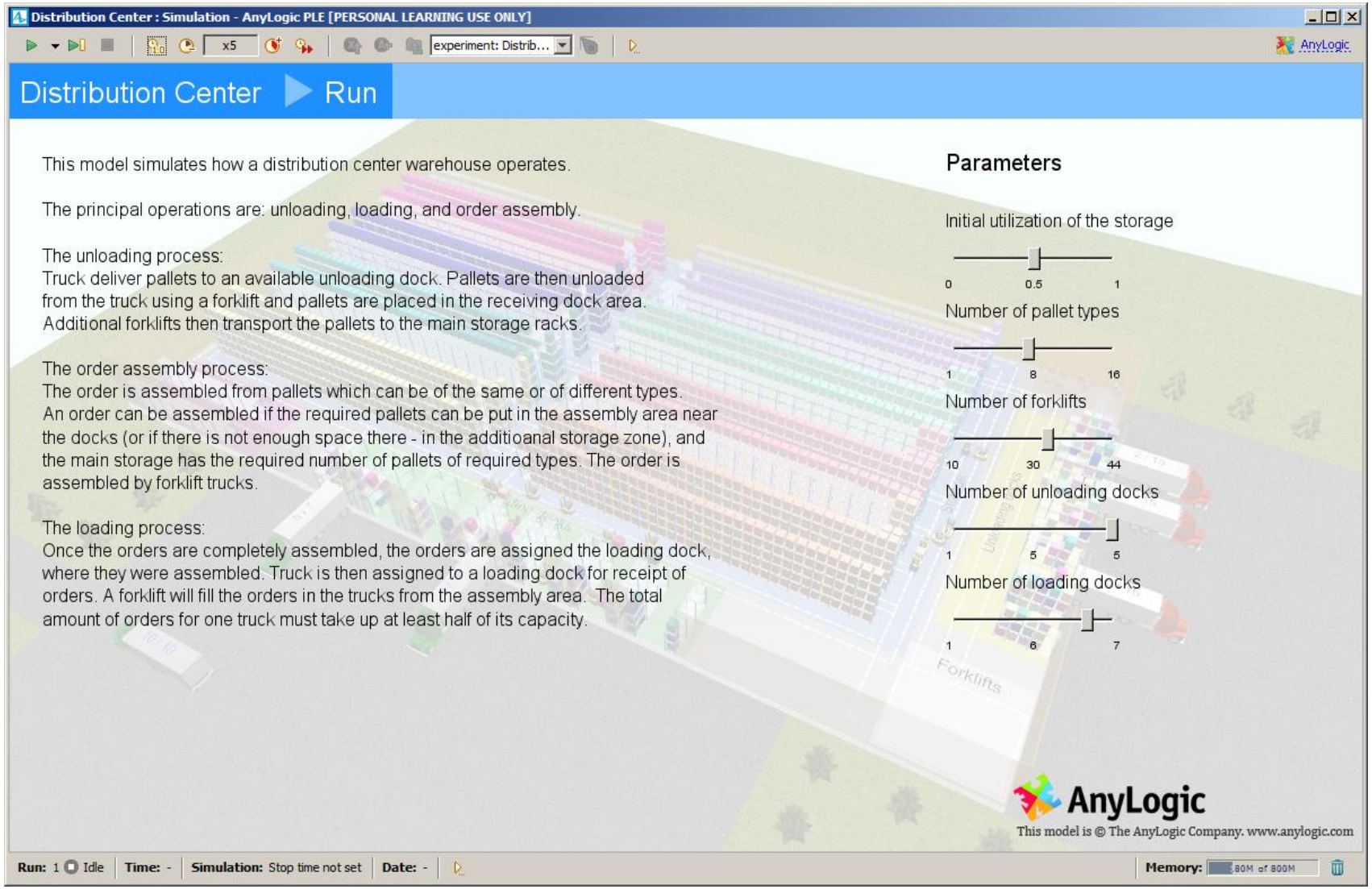
Job Shop : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x10
experiment: Job S...
AnyLogic
Job Shop
Run
This model simulates the manufacturing and shipping process in a small job shop.
Raw material is delivered to the receiving dock, which is placed into storage until processing occurs at the CNC machine.
Finished parts are palletized, and then moved to storage at the shipping dock, until the completed pallets can be loaded on a truck.
The user can control certain model parameters, like process times and labor quantities,via the input boxes.
A metrics page charts labor utilization, as well as operating costs as a function of the user's chosen operating scheme.
Run: 1 Idle
Time: -
236.5 sec

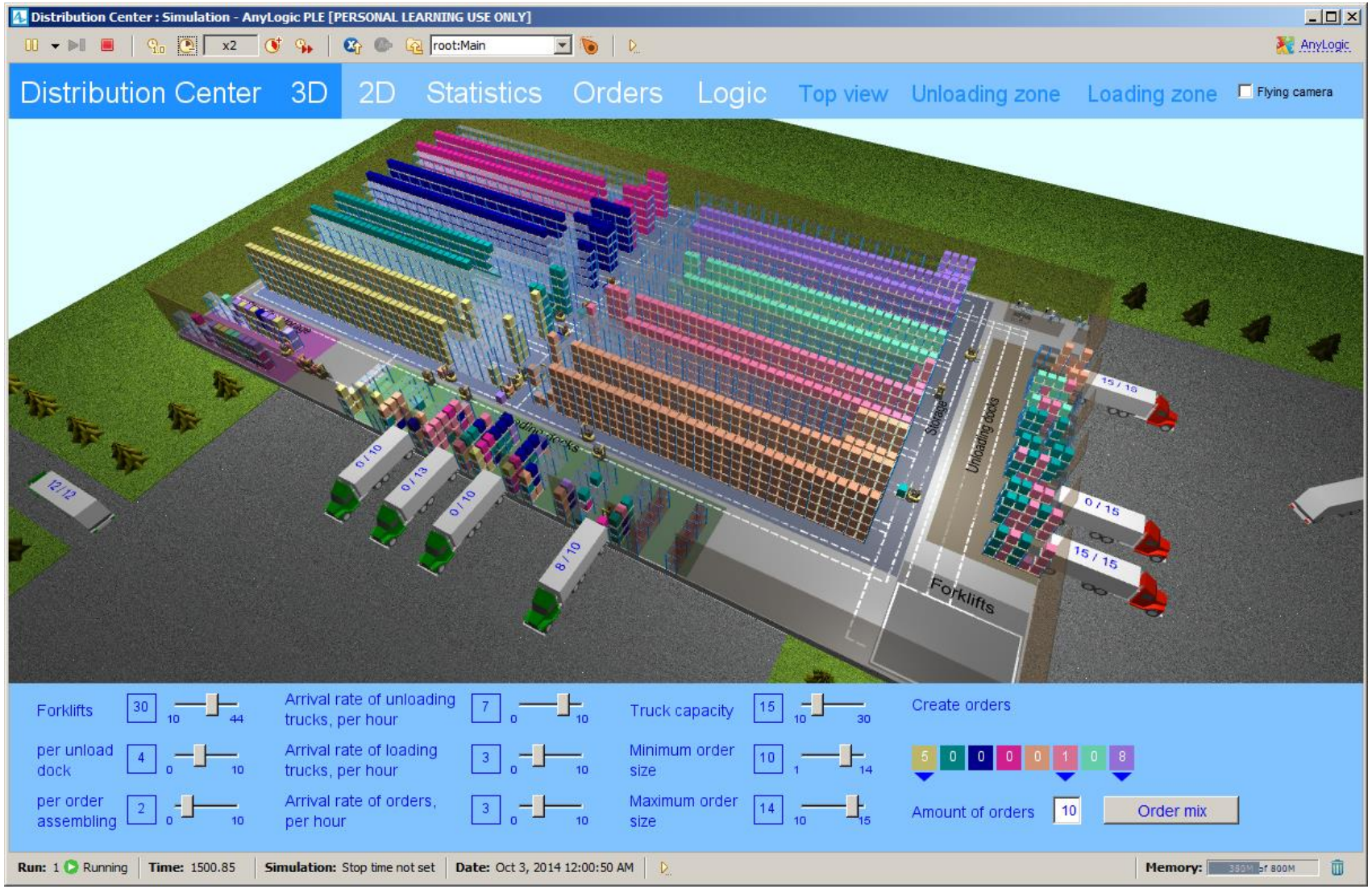

Job Shop : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x10
root:Main
AnyLogic
Job Shop
3D
2D
Statistics
Logic
Run: 0 Running
Time: 614.78
61.8 sec

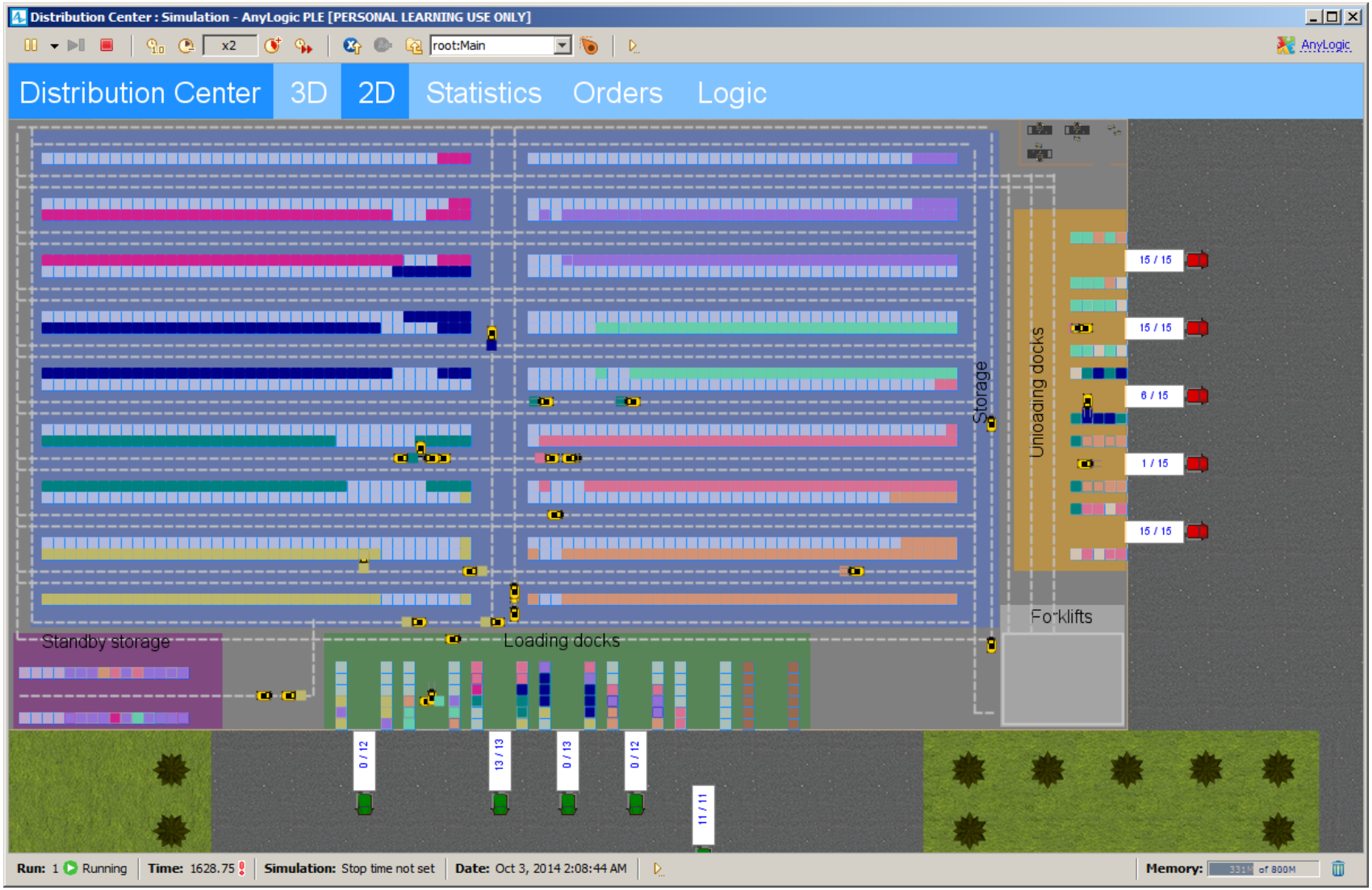

Job Shop : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x10
root:Main
AnyLogic
Job Shop
Flying camera
3D
2D
Statistics
Logic
Run: 0 Running
Time: 256.29
25.8 sec

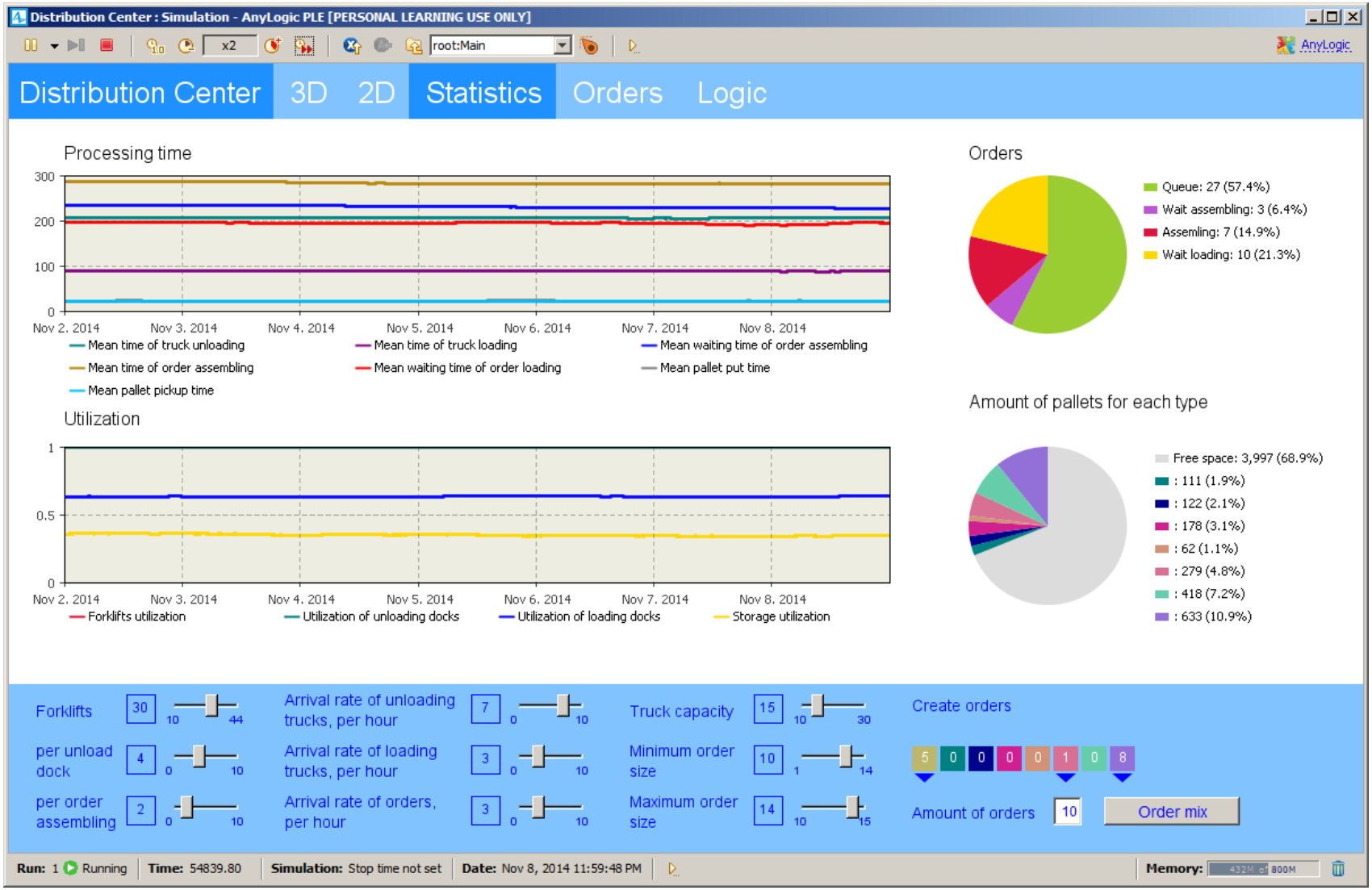

Job Shop : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x25
root:Main
AnyLogic
Job Shop
3D
2D
Statistics
Logic
DELIVERY
waitPallets
loadPallets
waitD
rasD
dropoffPallets
atDropOff
moveTo
raeD
deliveryTruckExits
sourceDeliveryTrucks
drivingToReceivingDock
waitParts
loadParts
sourcePallets
palletsToLoad
partsToLoad
sourceParts
cncMachineA
cncMachineB
cncMachineC
palletEnter
storeRawMaterial
rawMaterialInStorage
tms0
tme0
tms1
tme1
rasM
raeM
FinishedPartsInStorage
tms2
tme2
tms3
pickFinishedPallet
needLoadMore
finishedPalletsToLoad
tme3
STORAGE AND PROCESSING
SHIPPING
waitS
drivingToShippingDock
waitLoading
pickupPallets
drivingToExit
shippingTruckExits
sourceShippingTrucks
ShippingTruckArrival
rasS
raeS
ForkLift
24%
2/2
DeliveryTimeInterval
DeliveryShippingInterval
resetStats
PalletCapacity
TruckCapacity
NForkLifts
TruckSpeed
ForkLiftSpeed
WorkerSpeed
StoragePutDelay
StoragePickDelay
PickupPartDelay
PalletizingDelay
ProcessingTimeMin
ProcessingTimeMean
ProcessingTimeMax
Run: 1 Running
Time: 1060.49
46.4 sec

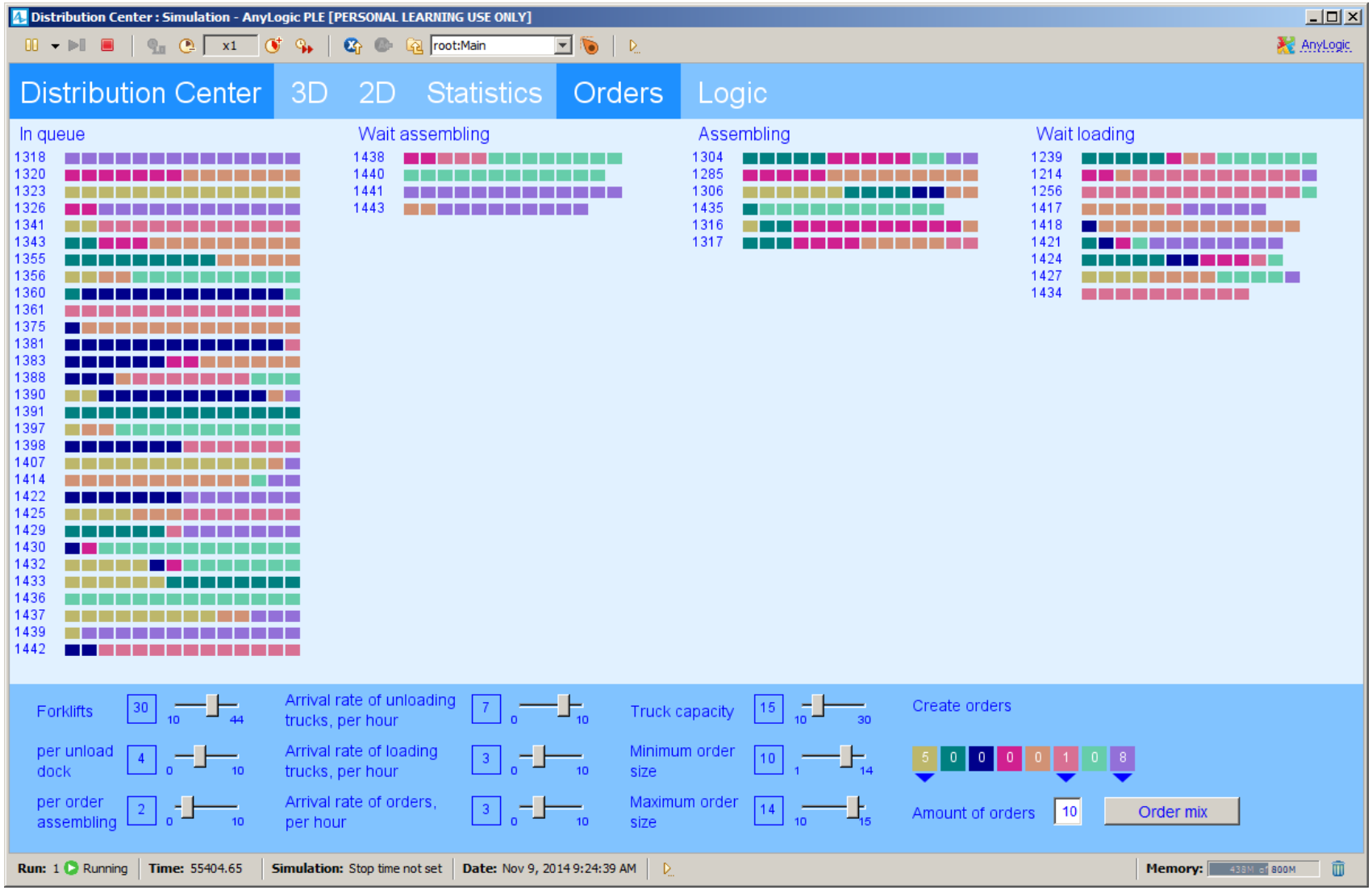

Job Shop : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x25
cncMachineA
AnyLogic
tms0
pickRawPallet
dropoffRawParts
waitAllPartsFinished
pickupFinishedParts
storeFinishedPallet
tme2
onePalletAtMachine
tme0
tms1
tme1
tms2
onePalletAtMachineEnd
waitMachineAvailable
toMachine
processing
toPallet
bufferPartsFinished
partEnter
onePartInMachineStart
onePartAtMachineEnd
Worker
5%
1/1
forkLift
resetStats
root.ForkLift: ResourcePoolAll units: 2Active: 2Idle units: 2 Utilization:0.116...
PalletLocation
com.anylogic.engine.markup.Re...
WorkerSpeed
1
StoragePickDelay
PickupRawPartDelay
ProcessingTime
PalletizingDelay
StoragePutDelay
Run: 1 Running
Time: 4110.61
168.4 sec

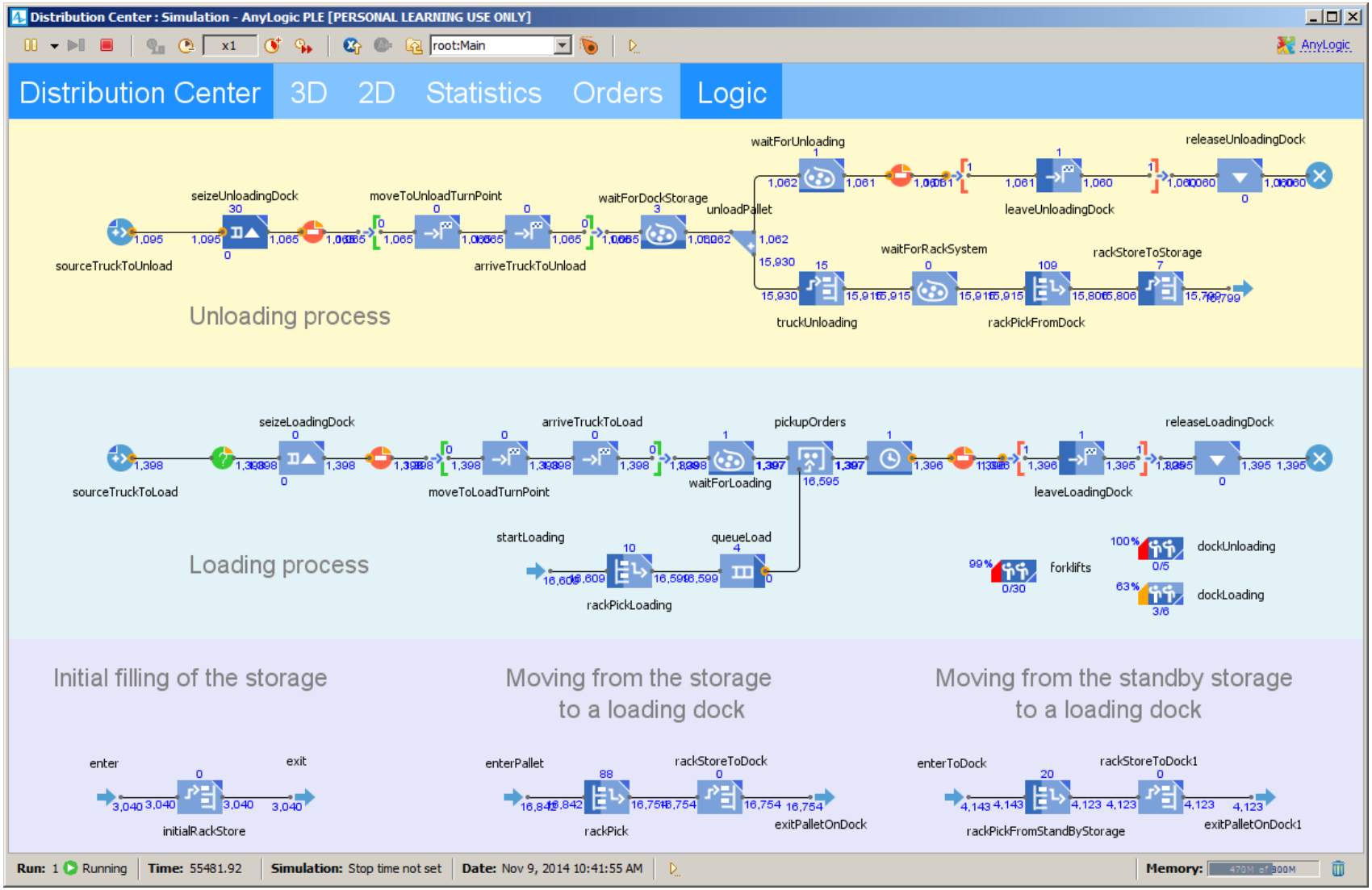

Distribution Center : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x5
experiment: Distrib...
AnyLogic
Distribution Center
Run
This model simulates how a distribution center warehouse operates.
The principal operations are: unloading, loading, and order assembly.
The unloading process:
Truck deliver pallets to an available unloading dock. Pallets are then unloaded from the truck using a forklift and pallets are placed in the receiving dock area. Additional forklifts then transport the pallets to the main storage racks.
The order assembly process:
The order is assembled from pallets which can be of the same or of different types. An order can be assembled if the required pallets can be put in the assembly area near the docks (or if there is not enough space there - in the additioanal storage zone), and the main storage has the required number of pallets of required types. The order is assembled by forklift trucks.
The loading process:
Once the orders are completely assembled, the orders are assigned the loading dock, where they were assembled. Truck is then assigned to a loading dock for receipt of orders. A forklift will fill the orders in the trucks from the assembly area. The total amount of orders for one truck must take up at least half of its capacity.
Parameters
Initial utilization of the storage
0
0.5
1
Number of pallet types
1
8
16
Number of forklifts
10
30
44
Number of unloading docks
1
5
5
Number of loading docks
1
6
7
Forklifts
AnyLogic
This model is © The AnyLogic Company. www.anylogic.com
Run: 1 Idle
Time: -
Simulation: Stop time not set
Date: -
Memory:
80M of 800M


Distribution Center : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x2
root:Main
AnyLogic
Distribution Center
3D
2D
Statistics
Orders
Logic
Top view
Unloading zone
Loading zone
Flying camera
Storage
Unloading docks
Forklifts
Forklifts
30
10
44
per unload dock
4
0
10
per order assembling
2
0
10
Arrival rate of unloading trucks, per hour
7
0
10
Arrival rate of loading trucks, per hour
3
0
10
Arrival rate of orders, per hour
3
0
10
Truck capacity
15
10
30
Minimum order size
10
1
14
Maximum order size
14
10
15
Create orders
5
0
0
0
0
1
0
8
Amount of orders
10
Order mix
Run: 1 Running
Time: 1500.85
Simulation: Stop time not set
Date: Oct 3, 2014 12:00:50 AM
Memory:


Distribution Center : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x2
root:Main
AnyLogic
Distribution Center
3D
2D
Statistics
Orders
Logic
Storage
Unloading docks
15 / 15
15 / 15
6 / 15
1 / 15
15 / 15
Forklifts
Standby storage
Loading docks
0 / 12
13 / 13
0 / 13
0 / 12
11 / 11
Run: 1 Running
Time: 1628.75
Simulation: Stop time not set
Date: Oct 3, 2014 2:08:44 AM
Memory:


Distribution Center : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x2
root:Main
AnyLogic
Distribution Center
3D
2D
Statistics
Orders
Logic
Processing time
300
200
100
0
Nov 2, 2014
Nov 3, 2014
Nov 4, 2014
Nov 5, 2014
Nov 6, 2014
Nov 7, 2014
Nov 8, 2014
Mean time of truck unloading
Mean time of truck loading
Mean waiting time of order assembling
Mean time of order assembling
Mean waiting time of order loading
Mean pallet put time
Mean pallet pickup time
Utilization
1
0.5
0
Forklifts utilization
Utilization of unloading docks
Utilization of loading docks
Storage utilization
Orders
Queue: 27 (57.4%)
Wait assembling: 3 (6.4%)
Assemling: 7 (14.9%)
Wait loading: 10 (21.3%)
Amount of pallets for each type
Free space: 3,997 (68.9%)
: 111 (1.9%)
: 122 (2.1%)
: 178 (3.1%)
: 62 (1.1%)
: 279 (4.8%)
: 418 (7.2%)
: 633 (10.9%)
Forklifts
30
10
44
per unload dock
4
0
10
per order assembling
2
0
10
Arrival rate of unloading trucks, per hour
7
0
10
Arrival rate of loading trucks, per hour
3
0
10
Arrival rate of orders, per hour
3
0
10
Truck capacity
15
10
30
Minimum order size
10
1
14
Maximum order size
14
10
15
Create orders
5 0 0 0 0 1 0 8
Amount of orders
10
Order mix
Run: 1 Running
Time: 54839.80
Simulation: Stop time not set
Date: Nov 8, 2014 11:59:48 PM
Memory:

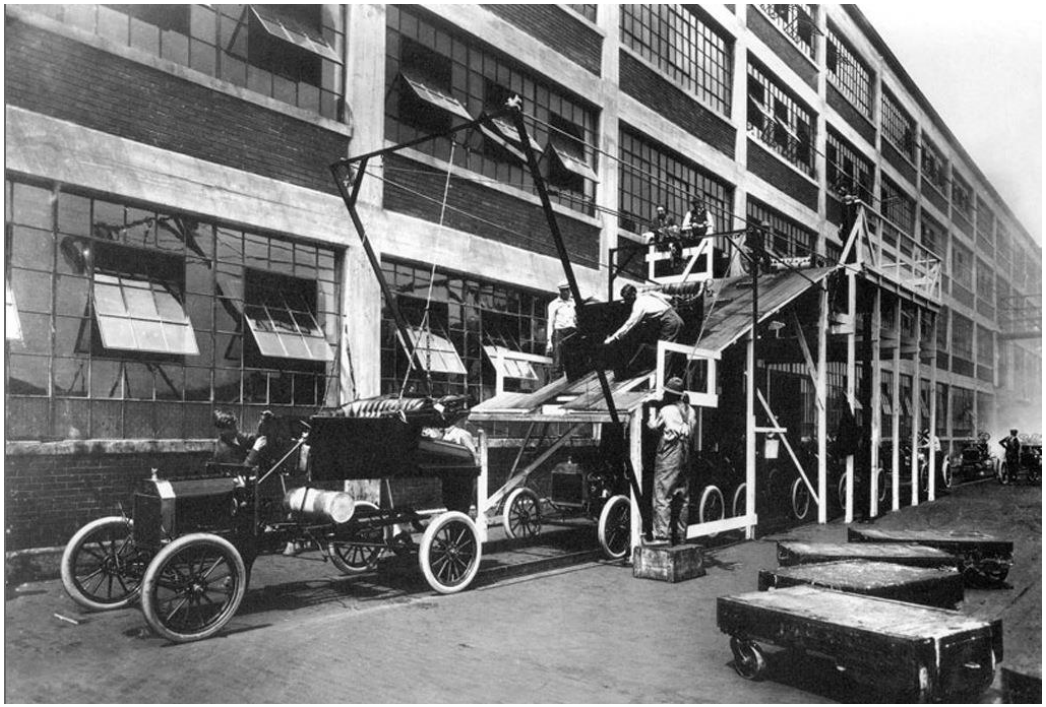

Distribution Center : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
x1
root:Main
AnyLogic
Distribution Center
3D
2D
Statistics
Orders
Logic
In queue
1318
1320
1323
1326
1341
1343
1355
1356
1360
1361
1375
1381
1383
1388
1390
1391
1397
1398
1407
1414
1422
1425
1429
1430
1432
1433
1436
1437
1439
1442
Wait assembling
1438
1440
1441
1443
Assembling
1304
1285
1306
1435
1316
1317
Wait loading
1239
1214
1256
1417
1418
1421
1424
1427
1434
Forklifts
30
10
44
per unload dock
4
0
10
per order assembling
2
0
10
Arrival rate of unloading trucks, per hour
7
0
10
Arrival rate of loading trucks, per hour
3
0
10
Arrival rate of orders, per hour
3
0
10
Truck capacity
15
10
30
Minimum order size
10
1
14
Maximum order size
14
10
15
Create orders
5
0
0
0
0
1
0
8
Amount of orders
10
Order mix
Run: 1 Running
Time: 55404.65
Simulation: Stop time not set
Date: Nov 9, 2014 9:24:39 AM
Memory:


Distribution Center : Simulation - AnyLogic PLE [PERSONAL LEARNING USE ONLY]
root:Main
AnyLogic
Distribution Center
3D
2D
Statistics
Orders
Logic
sourceTruckToUnload
seizeUnloadingDock
moveToUnloadTurnPoint
arriveTruckToUnload
waitForDockStorage
unloadPallet
waitForUnloading
leaveUnloadingDock
releaseUnloadingDock
truckUnloading
waitForRackSystem
rackPickFromDock
rackStoreToStorage
Unloading process
sourceTruckToLoad
seizeLoadingDock
moveToLoadTurnPoint
arriveTruckToLoad
waitForLoading
pickupOrders
leaveLoadingDock
releaseLoadingDock
startLoading
queueLoad
rackPickLoading
forklifts
dockUnloading
dockLoading
Loading process
Initial filling of the storage
enter
exit
initialRackStore
Moving from the storage to a loading dock
enterPallet
rackStoreToDock
rackPick
exitPalletOnDock
Moving from the standby storage to a loading dock
enterToDock
rackStoreToDock1
rackPickFromStandByStorage
exitPalletOnDock1
Run: 1 Running
Time: 55481.92
Simulation: Stop time not set
Date: Nov 9, 2014 10:41:55 AM
Memory:

Case Study (my PhD)

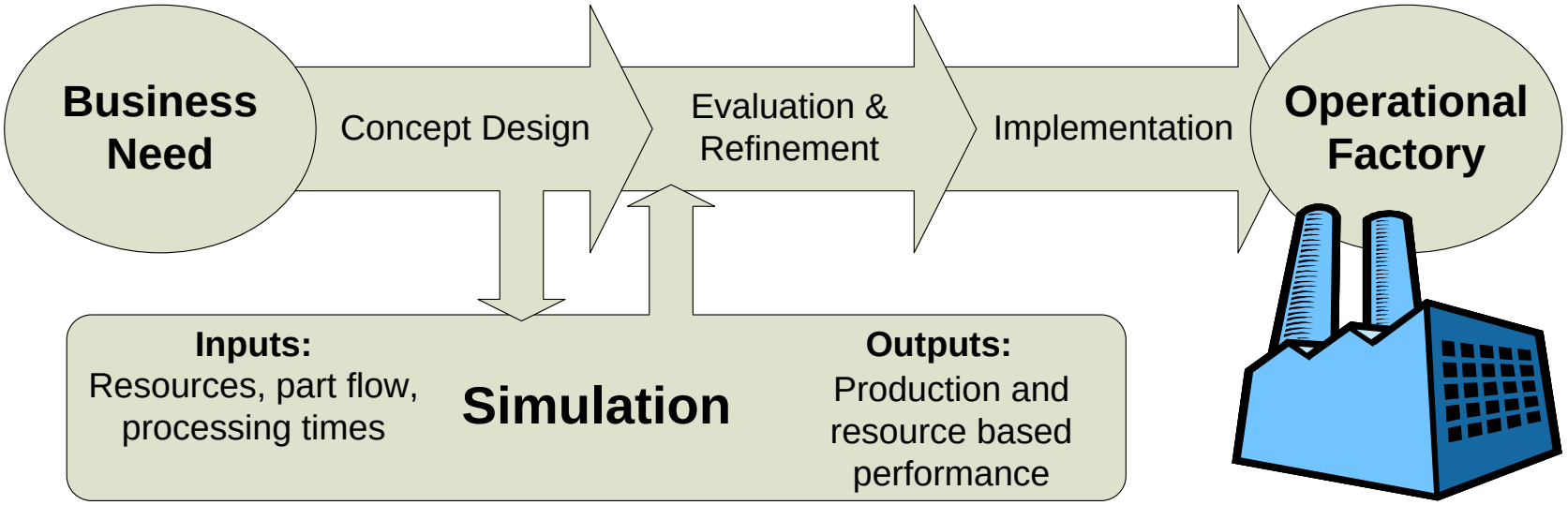
Case Study

- The Impact of Human Performance Variation on the Accuracy of Manufacturing Systems Simulation Models (Siebers 2004)



Case Study

- Manufacturing System Design Process



Case Study

- Statement:
  - Discrete Event Simulation (DES) is now a standard tool used for the design of manufacturing systems within the automotive industry

- Common Observations:
  - A gap exists between the performance prediction of a system model and the performance of the real system
  - Magnitude of the gap is bigger when simulating non existing systems
  - Magnitude of the gap is bigger when simulating manual lines
  - A standard way of taking workers into account is to model them as deterministic resources

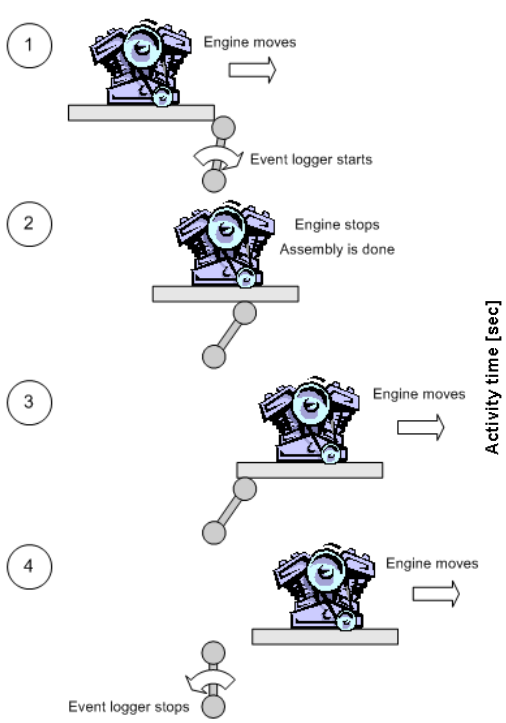
Case Study

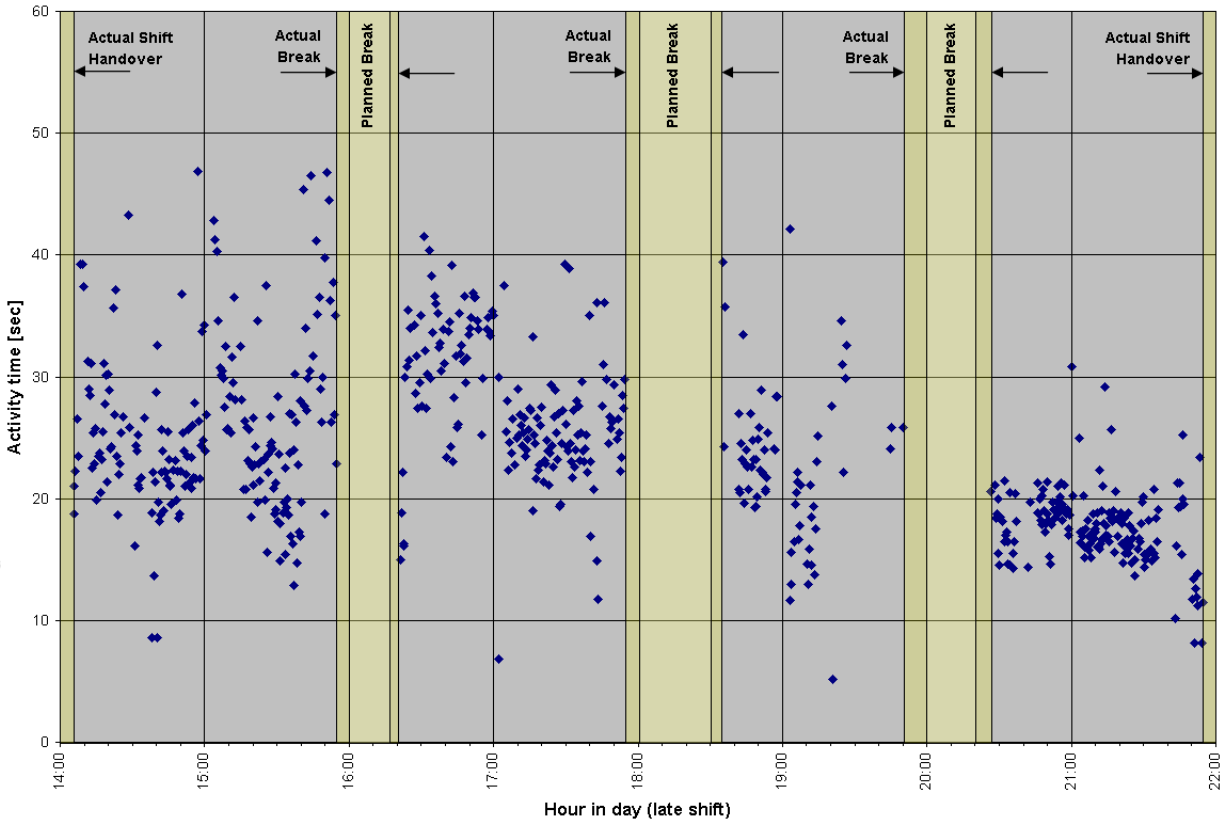
- Research Aim:
  - To demonstrate the importance of incorporating Human Performance Variation (HPV) models into manufacturing system simulation models

- Research Method:
  - Examine of the level of randomness inherent in HPV for different tasks
  - Design of representative HPV models
  - Sensitivity analysis to identify the impact that HPV has on the accuracy of manufacturing systems DES models
  - Literature review for more advanced methods of representing the human element within simulation models

Case Study

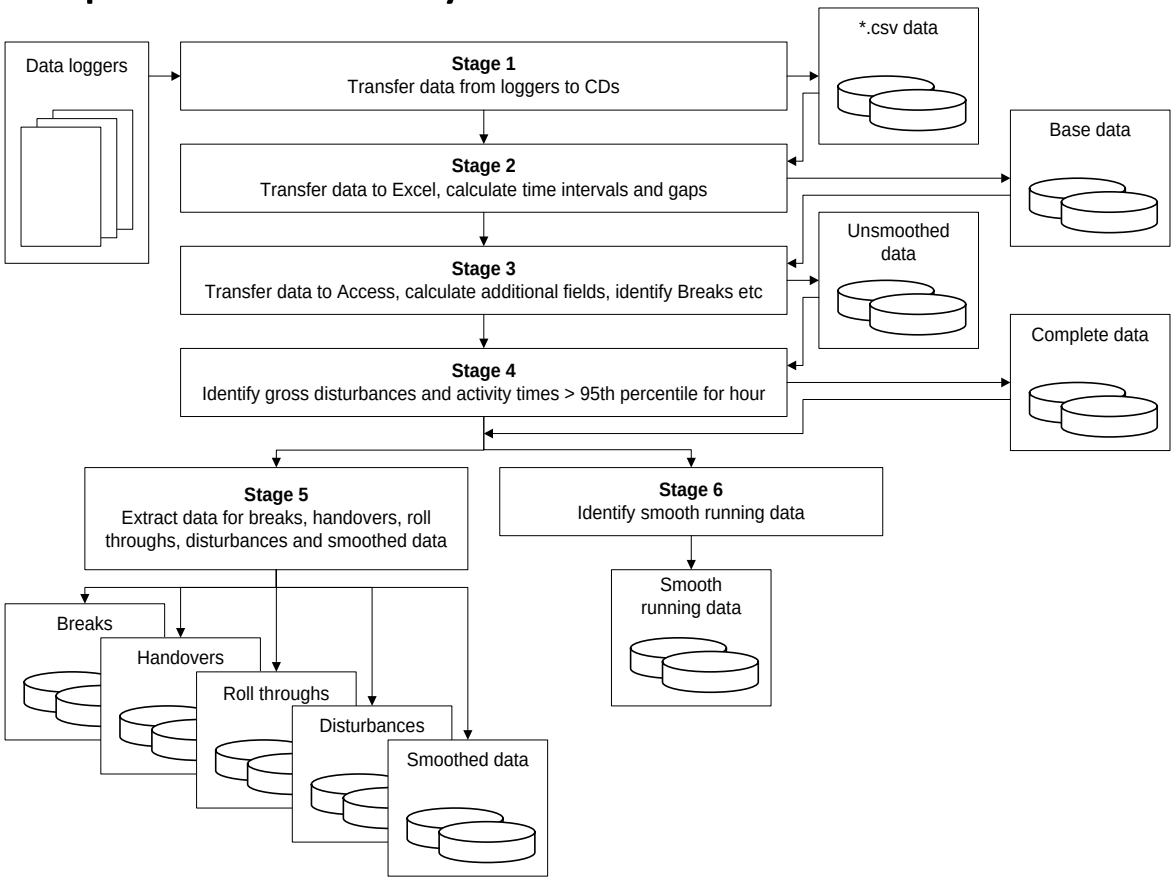
- Step 1: Examining the level of randomness





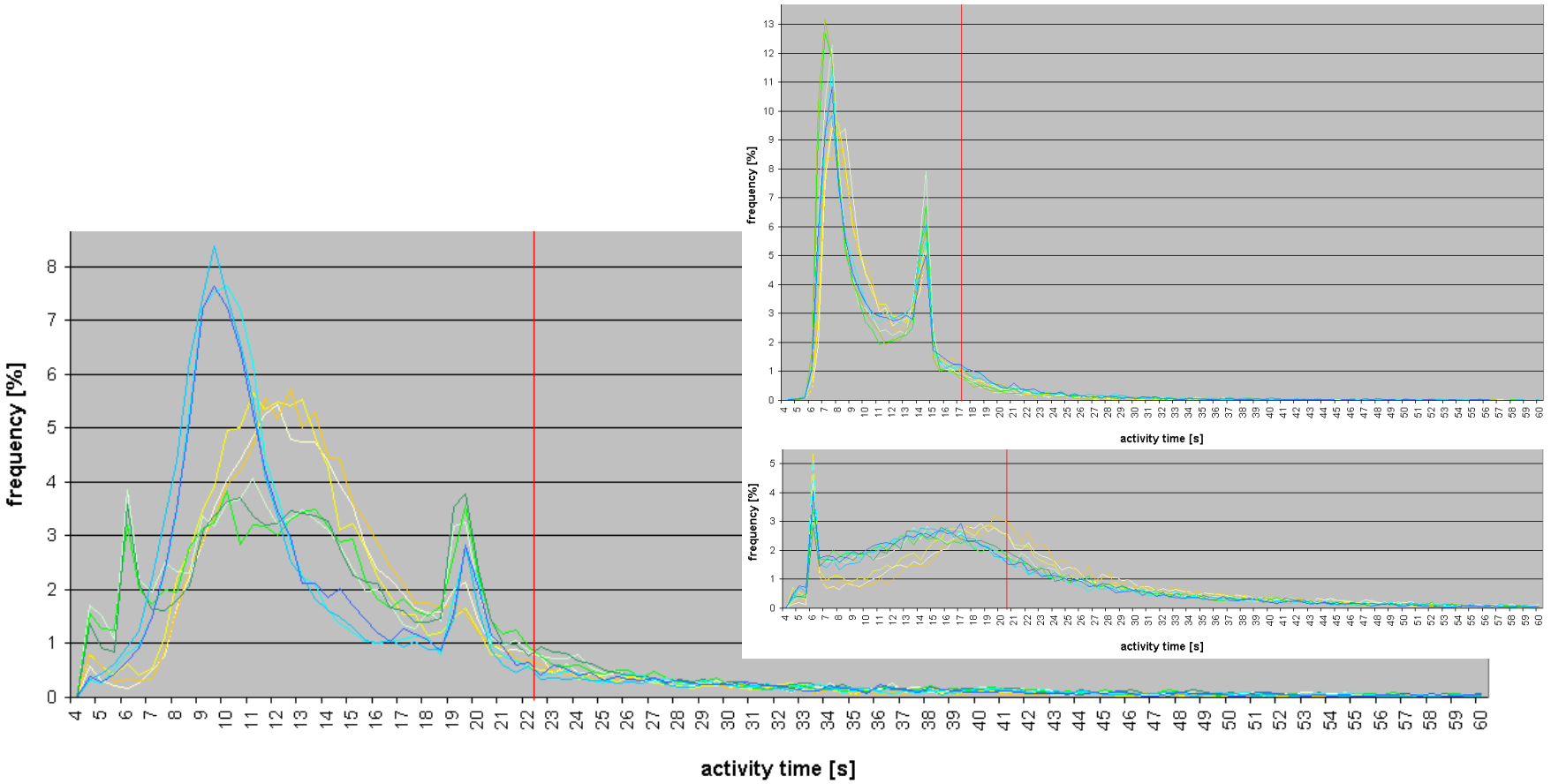
Case Study

- Step 2: Data analysis



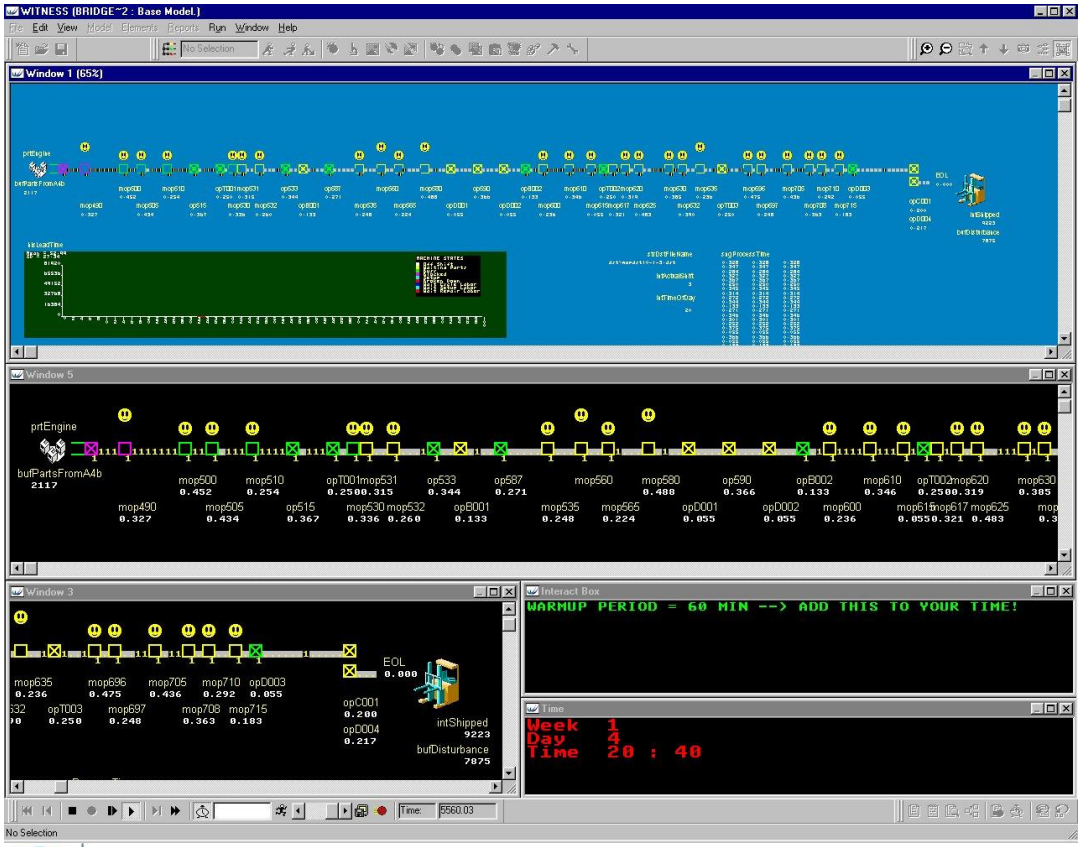
Case Study

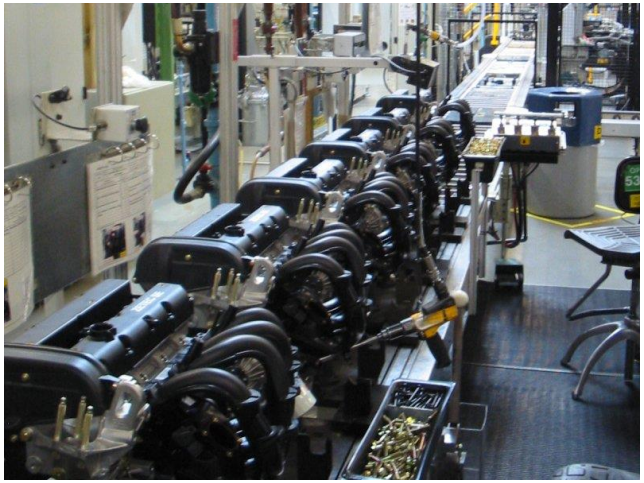
- Step 3: Designing HPV models



Case Study

- Step 4: Conducting sensitivity analysis





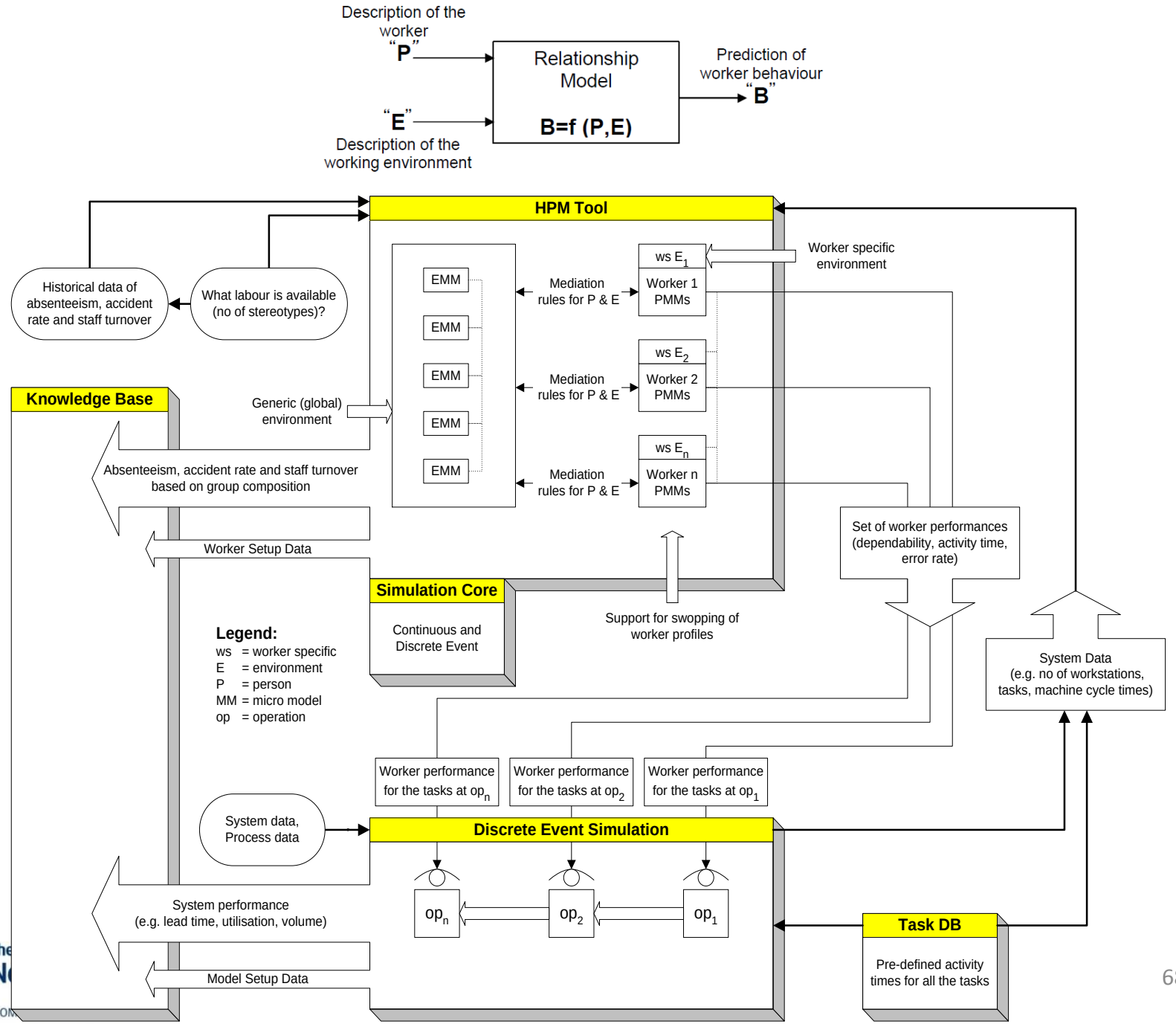
Case Study

- Key Findings about HPV:
  - Differences in activity times when workers repeat a task, between different workers, and between different work crews
  - Form of activity time distributions depends on the nature of the task
  - Variation of break start and duration does not depend on the length

- Key Findings from Sensitivity Analysis:
  - Representation of HPV can have a significant effect on the behaviour of manufacturing system simulation models
  - The magnitude of impact depends on the type of variation to be represented as well as on the system to be modelled

Case Study

- Main limitation of current HPV modelling approach:
  - Independent representation of sources of randomness
- Possible solution:
  - Using Computational Organisation Theory as a methodological approach and multi-agent based simulation as a technique
- Issues:
  - Complexity of the task
  - Concept of pro-activeness


Description of the worker "P"
"E" Description of the working environment
Relationship Model
B=f (P,E)
Prediction of worker behaviour "B"
HPM Tool
Historical data of absenteeism, accident rate and staff turnover
What labour is available (no of stereotypes)?
Knowledge Base
Generic (global) environment
EMM
EMM
EMM
EMM
EMM
Mediation rules for P & E
Mediation rules for P & E
Mediation rules for P & E
ws E1
Worker 1 PMMs
ws E2
Worker 2 PMMs
ws En
Worker n PMMs
Worker specific environment
Absenteeism, accident rate and staff turnover based on group composition
Worker Setup Data
Simulation Core
Continuous and Discrete Event
Support for swopping of worker profiles
Set of worker performances (dependability, activity time, error rate)
System Data (e.g. no of workstations, tasks, machine cycle times)
Legend:
ws = worker specific
E = environment
P = person
MM = micro model
op = operation
Worker performance for the tasks at opn
Worker performance for the tasks at op2
Worker performance for the tasks at op1
System data, Process data
Discrete Event Simulation
opn
op2
op1
System performance (e.g. lead time, utilisation, volume)
Model Setup Data
Task DB
Pre-defined activity times for all the tasks

Questions and Comments

References

References

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