

3D Simulation Modeling in Healthcare Environments

MEMORIAL
HERMANN

FACTS & FIGURES (FISCAL YEAR END 2009)

1 tertiary care teaching hospital for The University of Texas Medical School :

- Home of the nation's busiest Level I trauma center,
- Operates Houston's Life Flight® air ambulance program,
- Houston's only Burn Treatment Center,
- Children's Memorial Hermann Hospital,
- TIRR - one of the nation's top rehabilitation and research hospitals,
- Mischer Neuroscience Institute

8 suburban hospitals which include
3 premier Heart & Vascular Institutes

8 comprehensive cancer centers

21 imaging centers

8 breast care centers

10 surgery centers

25 sports medicine and rehabilitation centers

19 diagnostic laboratories

Annual emergency visits: 411,591

Annual deliveries: 26,731

Annual Life Flight air ambulance missions: 3,485

Employees: 20,840

Beds (acute licensed): 3,581

Medical staff members: 4,857

Physicians in training: 1,821 (physicians and fellows)

Annual payroll: \$1,087,570,000

Annual community benefit: Over \$300 million



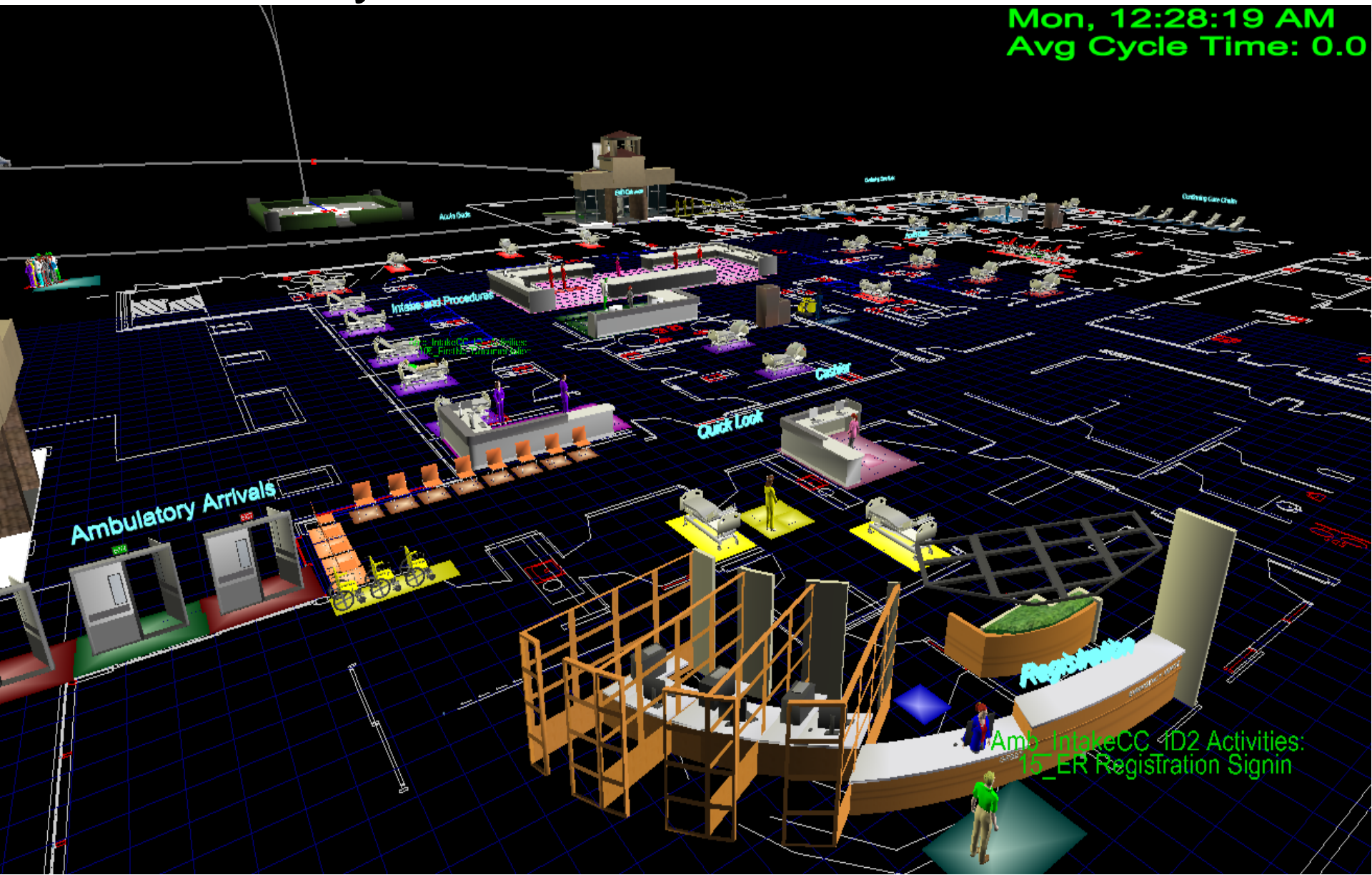
Last year, Memorial Hermann partnered with Flexsim® to simulate a new ER patient model recently implemented by developing unique patient tracks that account for the different patient flow patterns.



Simulation using 3D Hospital AutoCAD Layouts of ED Unit

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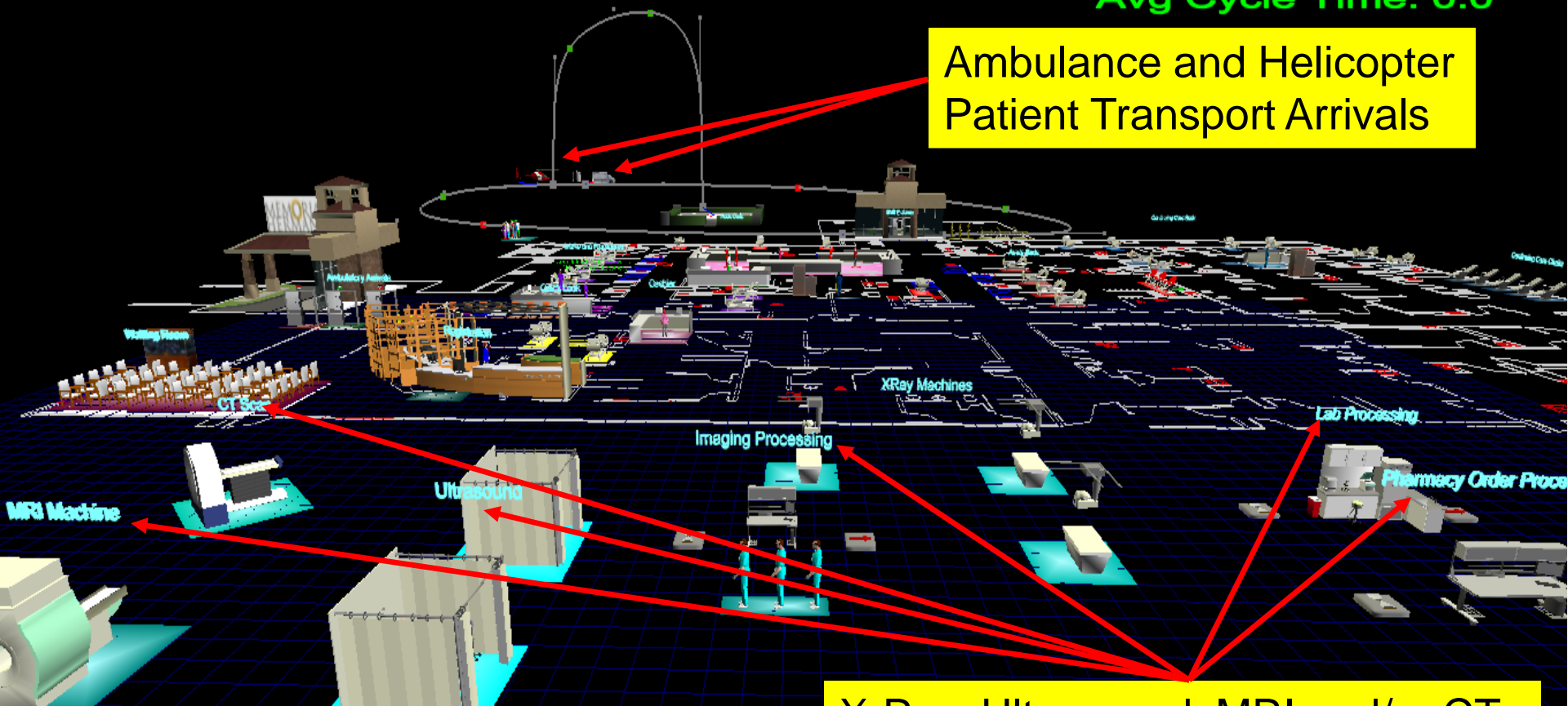
Mon, 12:28:19 AM
Avg Cycle Time: 0.0



Contributing Factors Outside ED

Mon, 12:10:20 AM
Avg Cycle Time: 0.0

Ambulance and Helicopter
Patient Transport Arrivals

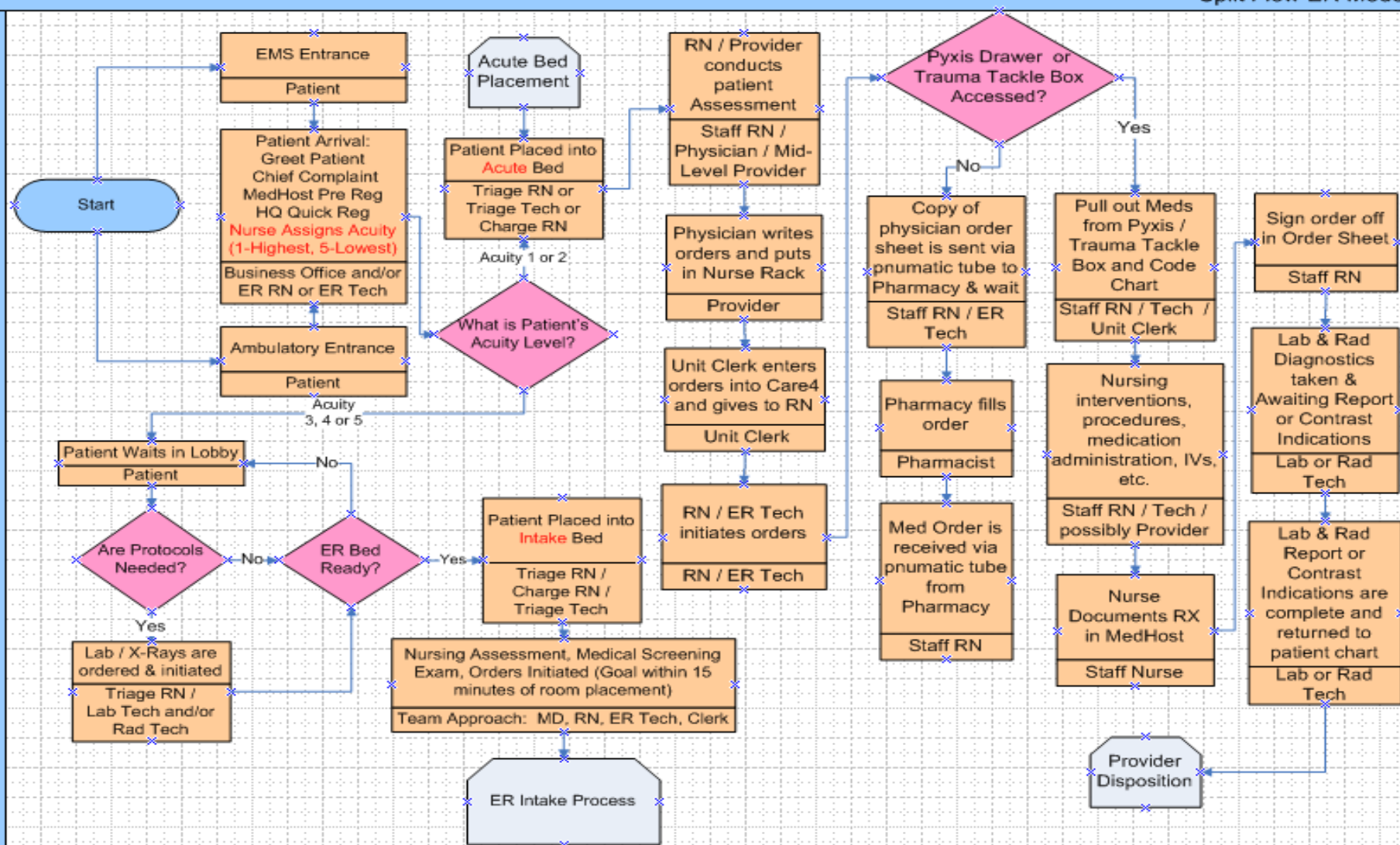


X-Ray, Ultrasound, MRI and/or CT
Imaging, Lab or Pharmacy Order
Processing outside of the ER Dept

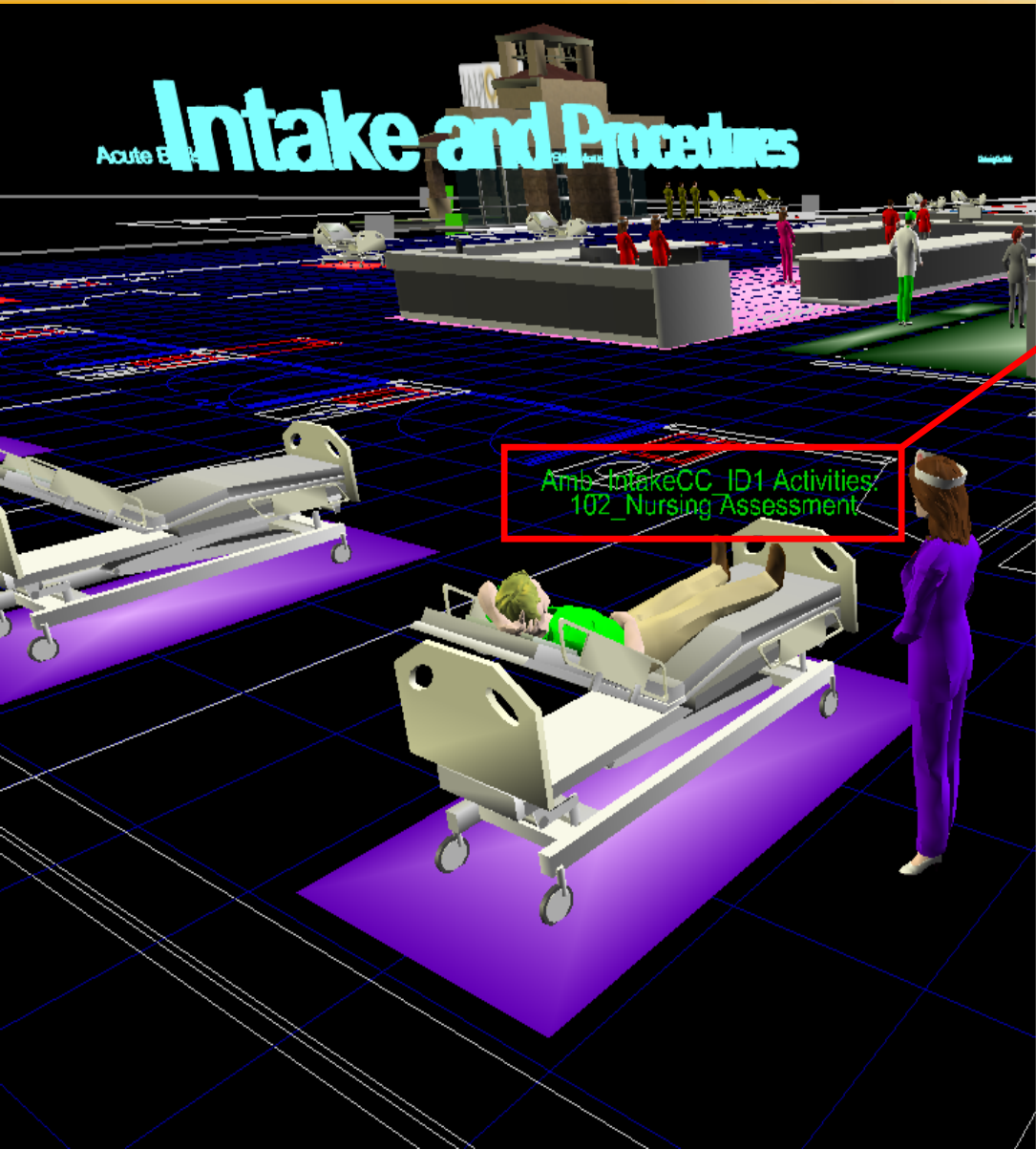
Patient Flow Diagram

Emergency Department Entry / Triage Process

Split Flow ER Model



Patient Track Manager



Track Manager

Tracks | Activities | Visuals | Files

Add	Move Up	Activity Name	102_Nursing Assessment	Activity ID	102.00	Predecessors	100	Milestone	RN Assessment	Start Time	
Remove	Move Down										

Total Activity Costs = 0.00 \$ + 0.00 \$/hr + allocat

Process Time: triangular(5,15,7)

Process Location: patient's location

Resource Allocation Priority: 0.00 | Preemption Rule: no preempting

Staff: Add | Delete

Nursing_IntakeGroup

Staff Assigned to Task

- 10_Arrival
- 15_ER Registration Signin
- 20_Pt to Waiting Room
- 30_Pt Goes to Quick Look
- 32_QuickLook Patient
- 34_Pt Finishes QL
- 50_Acuity Assessment
- 100_Move Pt to IntakeArea
- 102_Nursing Assessment
- 104_Protocol Orders Initiated
- 106_FirstNet Documentation
- 140_LWBS Decision
- 142_Pt Leaves LWBS
- 144_Pt Leaves ER
- 146_Patient Stays
- 148_Med Screening Placement
- 150_MD Med Screen Intake Pt
- 152_MD Examines Intake Pt
- 154_Scribe inputs orders in FN
- 156_ER Tech or RN Gets Orders
- 158_ER Tech or RN Initiates Orders
- 160_Skip to Lab Assessment
- 190_Assess Lab Needs
- 192_Draw Sample
- 194_Send Sample
- 196_Process Sample
- 200_Assess Rx Needs
- 205_Check Pyxis for Rx
- 210_Order sent to Pharmacy
- 215_Pharmacy Fills Orders
- 220_Pharmacy sends Rx in Tube
- 225_Rx retrieved from Pyxis or tube
- 230_Nurse Administers Drug
- 240_Tech Nurse Doc in FN
- 250_Assess Imaging Needs
- 260_Transport to MRI
- 262_MRI Procedure
- 264_Send MRI to Processor
- 265_Process MRI
- 266_Physician Reads MRI
- 267_Return Pt to Room
- 270_Transport to XRay
- 272_XRay Procedure
- 274_Send XRay to Processor
- 275_Process XRay
- 276_MD Reads XRay
- 277_Return Pt to Room

Advanced Functions | Track Name: Amb

Distributed Patient Processing



Patient Movement:

Arrival



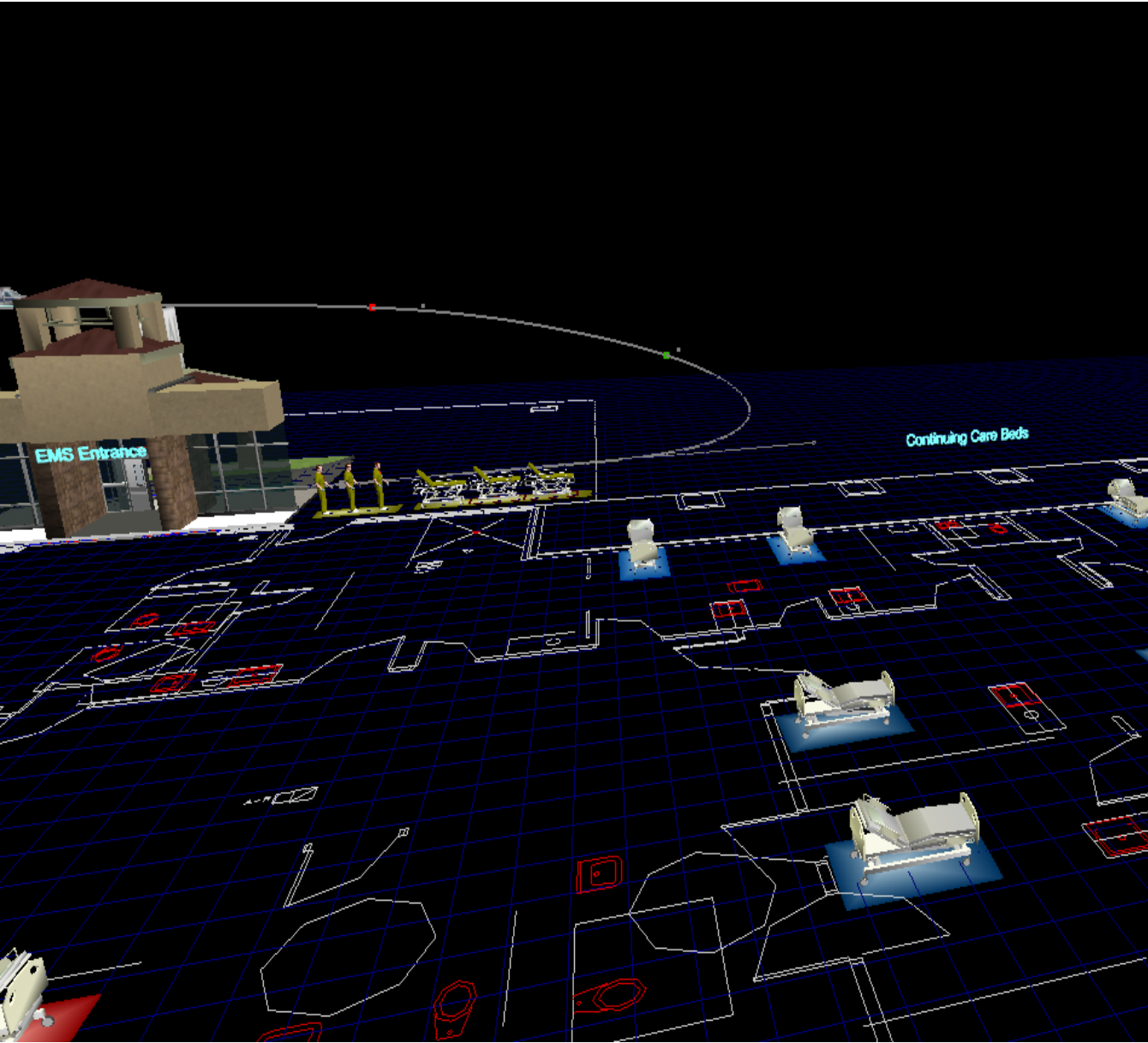
Quick Look



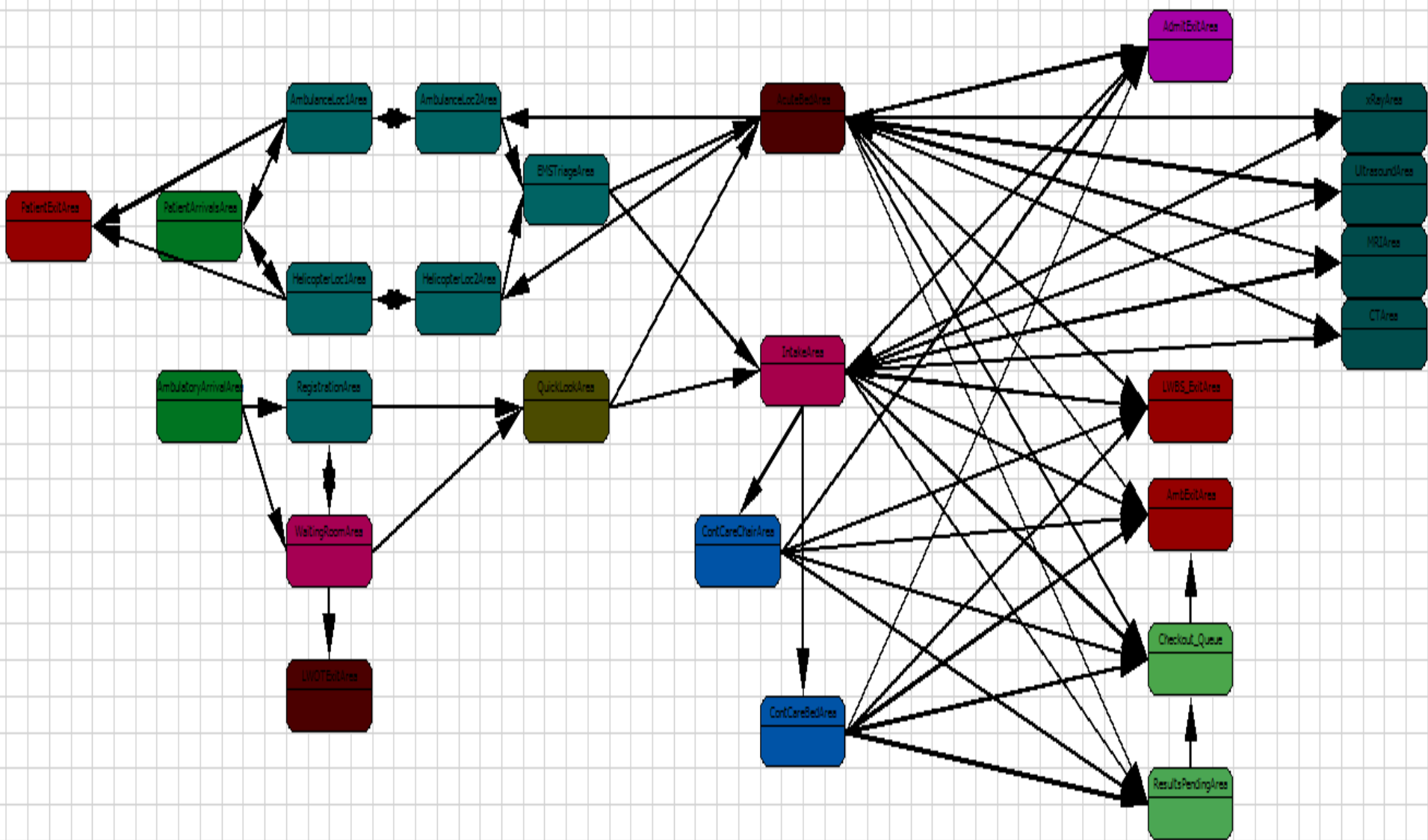
Intake



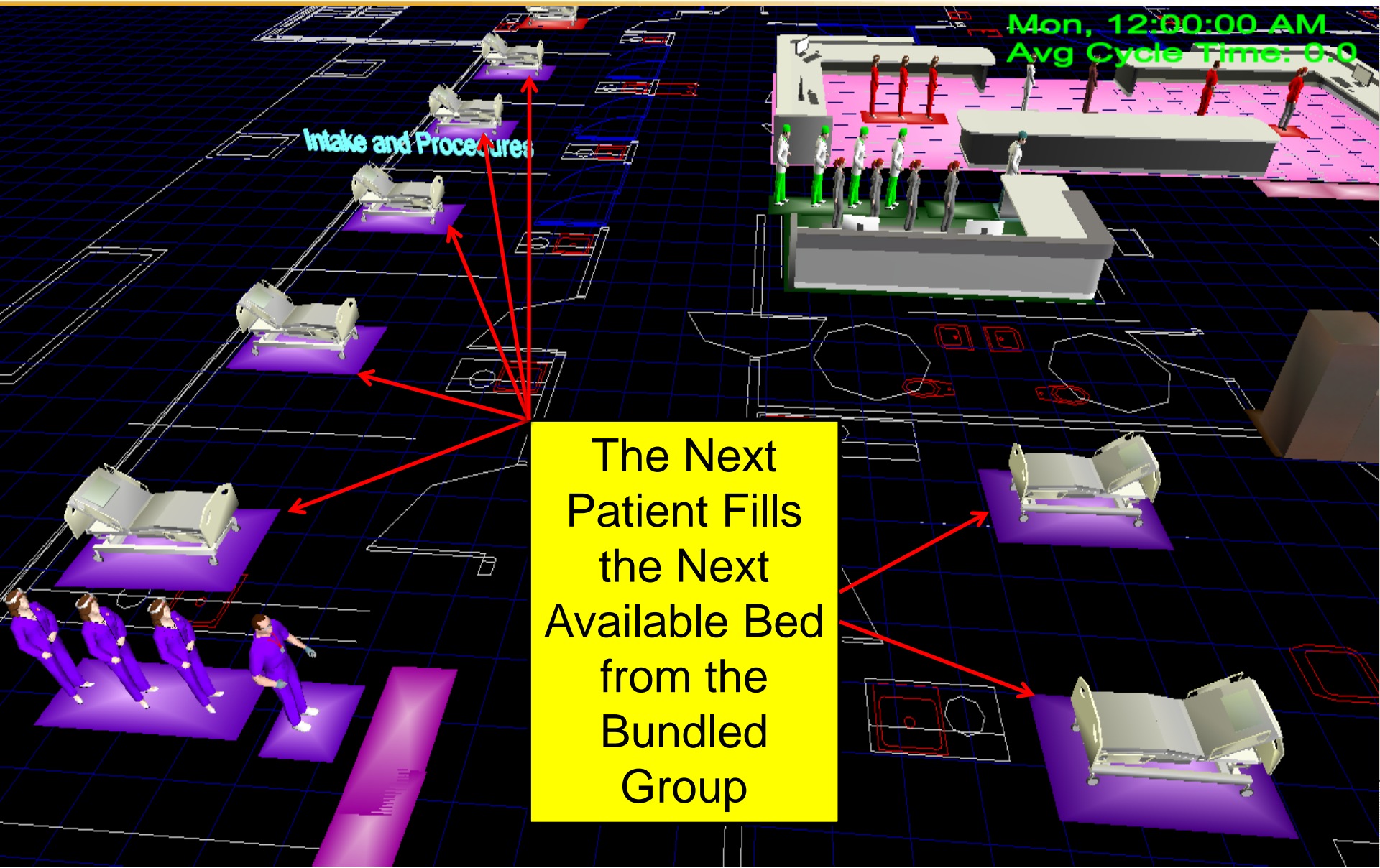
Acute or
Continuing Care



Drag & Drop Connections Simplifies Patient Flow to Bundled Areas



Staff and Beds are Bundled in Groups and Areas

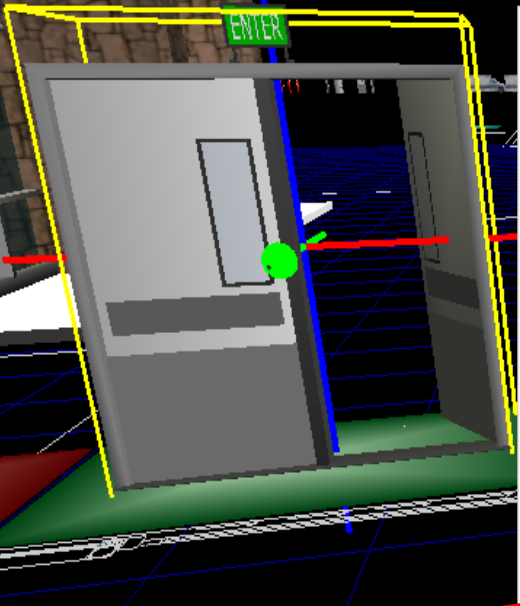


Patient Arrival Patterns Enter Simulation by Weekday and Hour of Day



Ambulatory Arrivals

Mon, 12:00:00 AM
Avg Cycle Time: 0.0



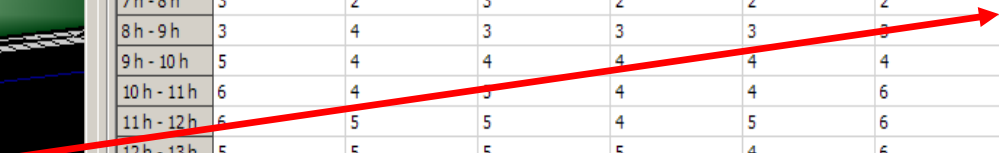
AmbulatoryArrival1 Properties

Name: AmbulatoryArrival1 Shape: Double Doors Area: AmbulatoryEntranceArea

Activate: Number of Patients Arriving During Each Hour of the Week

	Mon	Tue	Wed	Thu	Fri	Sat	Sun
0 h - 1 h	3	2	2	2	2	3	3
1 h - 2 h	2	2	2	2	2	2	2
2 h - 3 h	2	1	1	2	1	2	2
3 h - 4 h	2	1	1	1	1	2	2
4 h - 5 h	1	1	1	1	1	1	2
5 h - 6 h	2	1	1	1	2	2	1
6 h - 7 h	2	2	1	1	1	2	2
7 h - 8 h	3	2	3	2	2	2	2
8 h - 9 h	3	4	3	3	3	3	3
9 h - 10 h	5	4	4	4	4	4	5
10 h - 11 h	6	4	5	4	4	6	6
11 h - 12 h	6	5	5	4	5	6	7
12 h - 13 h	5	5	5	5	4	6	6
13 h - 14 h	5	4	5	4	4	6	5
14 h - 15 h	5	5	5	4	5	7	6
15 h - 16 h	4	4	5	5	5	5	5
16 h - 17 h	5	5	5	5	5	5	5
17 h - 18 h	6	6	5	6	5	7	6
18 h - 19 h	7	6	5	7	6	6	5
19 h - 20 h	7	6	6	6	6	5	6
20 h - 21 h	6	5	6	6	5	6	6
21 h - 22 h	5	5	5	5	6	5	6
22 h - 23 h	4	4	5	4	4	5	4
23 h - 24 h	3	3	3	4	4	4	3

Discrete Arrival Patterns within a given hour



How does the Simulation address patients that leave the ER of their own accord?

Patients leaving the ER fall into one of 3 classifications:

1. Left Without Triage (LWOT)

Patient leaves the Waiting Room before Triage takes place.

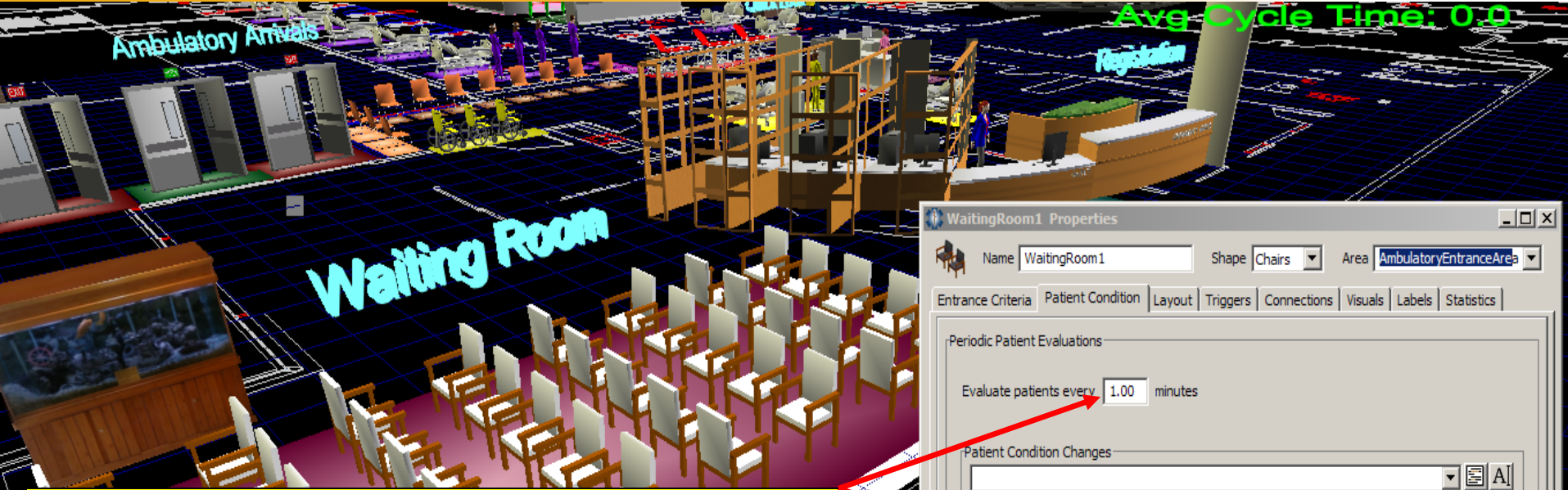
2. Left Without Being Seen (LWBS)

Patient is bedded but leaves before Doctor sees patient.

3. Against Medical Advice (AMA)

Patient does not like course of patient care given (i.e. surgery, hospital stay, etc.) by Doctor and leaves the ER against medical advice.

Left Without Triage (LWOT) MEMORIAL HERMANN



After the Waiting Room Occupancy has reached 10 patients, Acuity Level 1 Patients have a 1.6% chance of leaving for each minute that goes by.

WaitingRoom1 Properties

Name: WaitingRoom1 Shape: Chairs Area: AmbulatoryEntranceArea

Entrance Criteria Patient Condition Layout Triggers Connections Visuals Labels Statistics

Periodic Patient Evaluations

Evaluate patients every: 1.00 minutes

Patient Condition Changes

Patient Leaves Early

Determine whether a patient will leave early

Early Exit Condition: `content(current) > 10`

Early Exit Probabilities (%):

- Acuity 1 Patients: 1.6
- Acuity 2 Patients: 1.2
- Acuity 3 Patients: 0.8
- Acuity 4 Patients: 0.4
- Acuity 5 Patients: 0.0

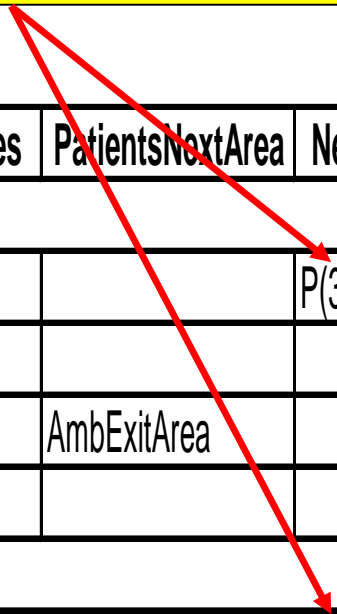
Apply OK

LWBS & AMA are addressed in the Patient Track Editor

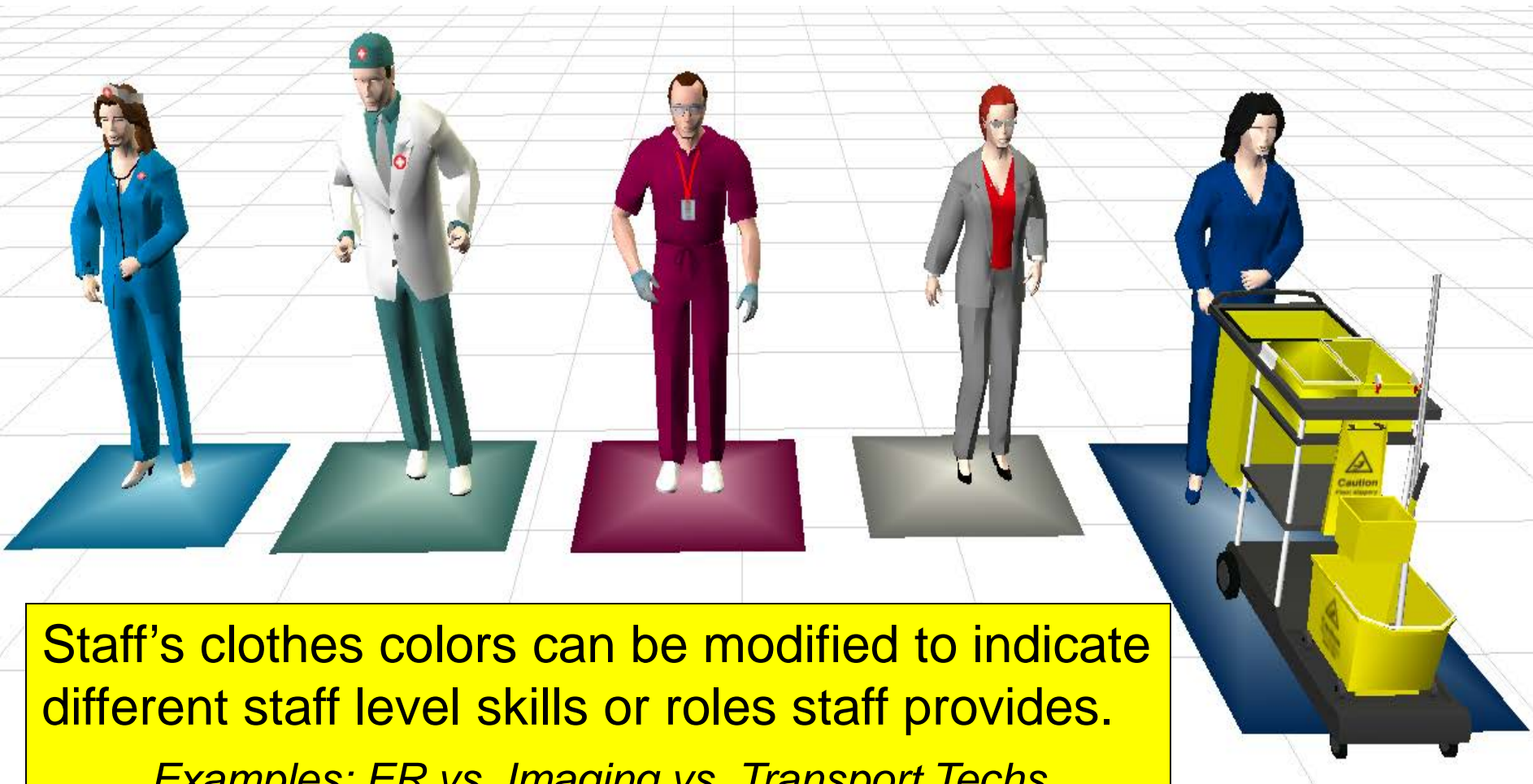
Track Name: Amb_IntakeCC

LWBS and AMA patients have a 3% chance of leaving the ER.

ActivityID	ActivityName	ActivityType	Predecessors	Milestones	PatientsNextArea	NextActivityChooser
140	140_LWBS Decision	Process	106			P(3,142,97,146))
142	142_Pt Leaves LWBS	PatientTravelsUnattended	142	LWBS		
144	144_Pt Leaves ER	PatientTravelsUnattended	142		AmbExitArea	
146	146_Patient Stays	Process	146			
420	420_Decision to Leave AMA	Process	412			P(3,422,97,426))
422	422_Pt Leaves AMA	PatientTravelsUnattended	422	AMA		
424	424_Pt Exits ER	PatientTravelsUnattended	422		AmbExitArea	
426	426_Patient Stays	Process	426			14



Staff Groups



Staff's clothes colors can be modified to indicate different staff level skills or roles staff provides.

Examples: ER vs. Imaging vs. Transport Techs

or

RN vs. LVN vs. PCA

Staff Scheduling

The screenshot displays the Flexsim Healthcare simulation environment. The main window shows a 3D perspective view of a hospital floor plan with various rooms and staff models. A red arrow points from a menu item to a specific staff model. The menu is open, showing a list of options under 'Shift Schedules'. The 'Nurse1_Float' option is selected. The simulation is running at a speed of 718. The time is 12:00:00 AM, and the average cycle time is 0.0. The interface includes a menu bar, a toolbar, and several panels for editing and monitoring the simulation.

Flexsim Healthcare - C:\Flexsim Models\ER\ER Models\KT ER v51.fsm

File Tools Help

Global Tables
Shift Schedules
Random Interrupts
Global Activity Lists
Presentation
Preload Media
User Events
Run Triggers
User Commands
Global Variables
Script Window
Output Console
Model Tree View
ExpertFit...
Model Documentation
Excel
Model Maintenance

Floor Plan Utilities
All_24Hours
MidLevel_Provider
Nurse1_Float
Clerk1_ContCare
ERTech1_ContCare
ERTech1_QuickLook
Nurse2_ContCare
Nurse2_Intake
Nurse3_AcuteCare
Nurse3_Intake
Physician1
Scribe1
Physician2
Scribe2
Physician3
Scribe3
Physician4
Scribe4
Add
Delete

Output Dashboard Experiment Saved Views: AmbArrival Tab
Run Speed: 718 Stop Time: -none-

Mon 12:00:00 AM
Avg Cycle Time: 0.0

Presentation Edit Panel
Run Control: Run Step Stop
Fly Paths: path1 New Path Delete Path
Fly Points: Point1 New Point Delete Point Update Point Time: 0

Dashboard 1
Tab 1 Tab 2 Tab 3 Tab 4

Start Flexsim Healthcare - ... Flexsim Orientation.ppt [...] untyped - Paint 8:50 AM

Staff Scheduling

The screenshot displays the Flexsim Healthcare interface. On the left, the 'Shift Scheduler' window is open, showing a list of objects in the model and members assigned to a shift named 'Nurse1_Float'. The 'Down Function' is set to 'Return to a Home Location' and the 'Resume Function' is 'Set Object State \nState: STAT_WaitingForTask'. The 'Daily/Weekly Time Table Entry' window is also open, showing a grid for scheduling staff by day of the week and hour of day. The simulation start time is set to Monday at 12 AM. A red arrow points from the 'Daily/Weekly Time Table Entry' window to a 3D simulation view on the right. The simulation view shows a hospital environment with staff members and a text overlay indicating 'Mon 12:00:00 AM Avg Cycle Time: 0.0'. A yellow callout box is overlaid on the simulation view, containing the text: 'Individualized scheduling is available for each staff position by day of week and hour of day.'

Individualized scheduling is available for each staff position by day of week and hour of day.

Contingency Staff Based on Customized Skill Rankings

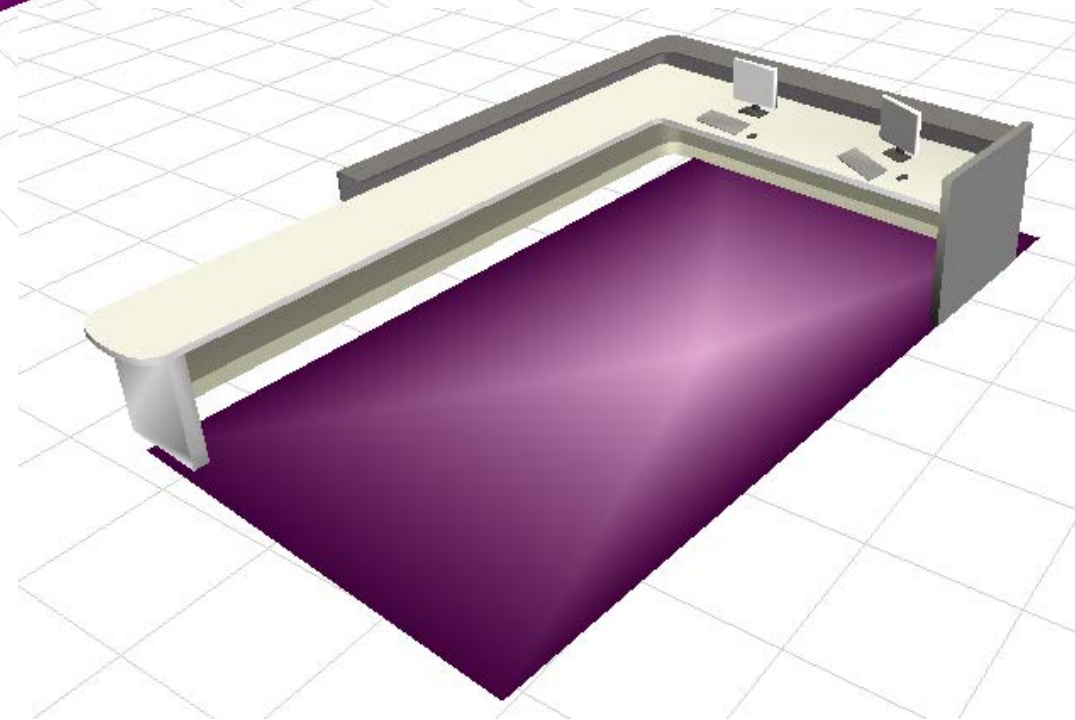
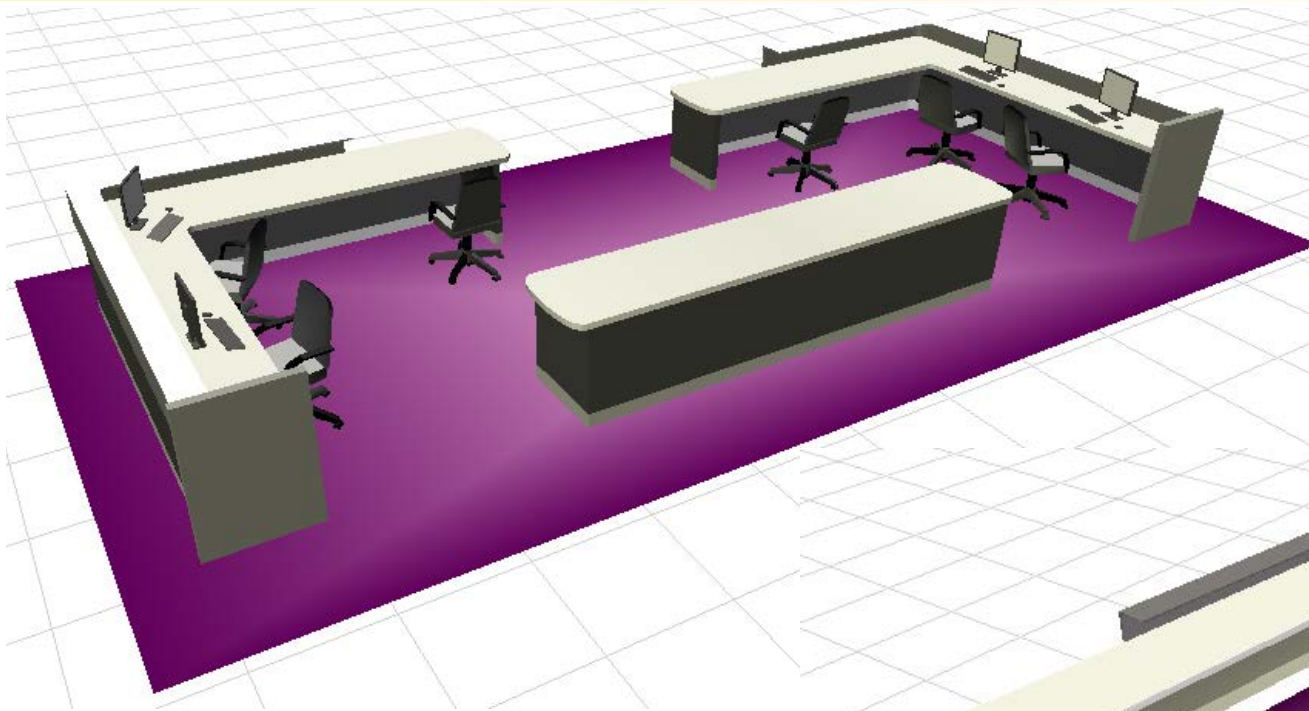
The image shows a screenshot of the Track Manager software interface. The main window displays the configuration for an activity named "102_Nursing Assessment". The activity is a "Process" with an ID of 102.00 and a predecessor of 100. The process time is defined as triangular(5, 15, 7). The process location is set to "patient's location". The resource allocation priority is 0.00, and the preemption rule is "no preempting".

In the "Staff" section, a table lists the staff assigned to the activity:

Staff
AltNurs_ITACCC

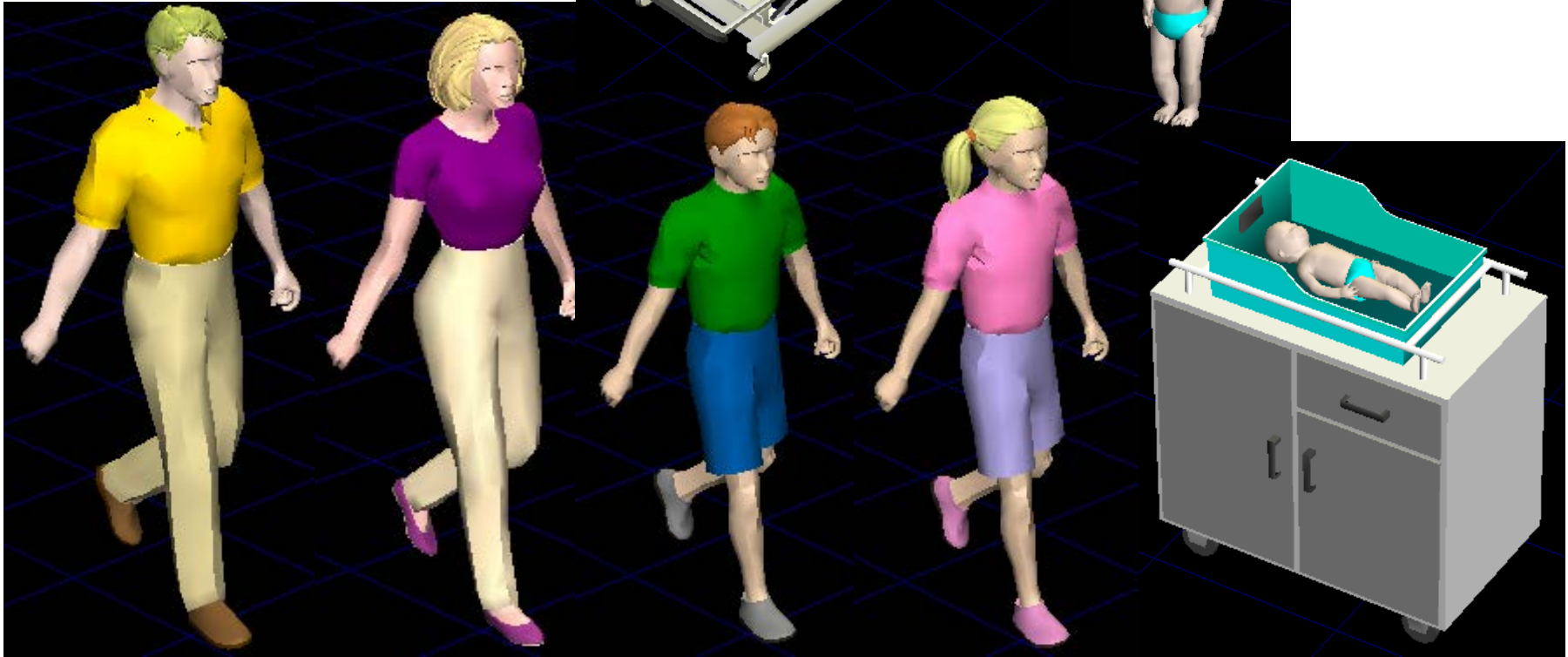
The "AltNurs_ITACCC" staff entry is circled in red. A red arrow points from this entry to the "AltNurs_ITACCC Properties" dialog box. In this dialog, the "Name" field is set to "AltNurs_ITACCC" and is also circled in red. The dialog shows two panels of objects. The left panel lists various groups and staff, including "AmbulanceGroup1", "Nursing_QuickLook", and "Nurse1_Charge". The right panel lists "Nursing_IntakeGroup", "Nursing_FloatGroup", "Nursing_AcuteCareGroup", "Nursing_ContCareGroup", and "Nursing_ChargeGroup". The "Nursing_IntakeGroup" entry in the right panel is circled in red. Below the panels are "Change order" buttons for "Rank ^" and "Rank v".

Patient Processing: Nursing Stations

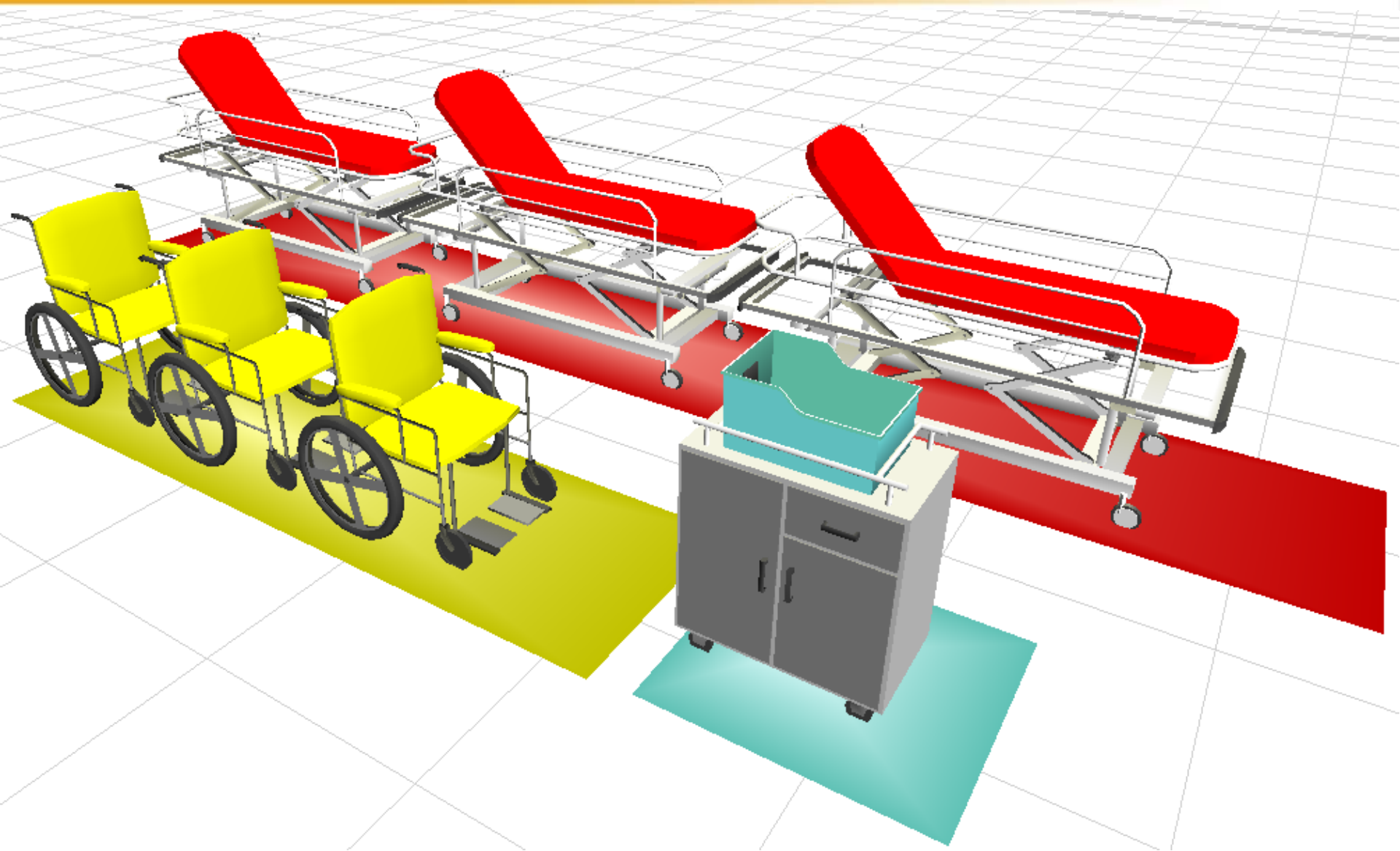


Patient Groups

Changes in Adult and Pediatric patient acuity, point of origination, etc. can “trigger” changes in shirt color.



Patient Transports



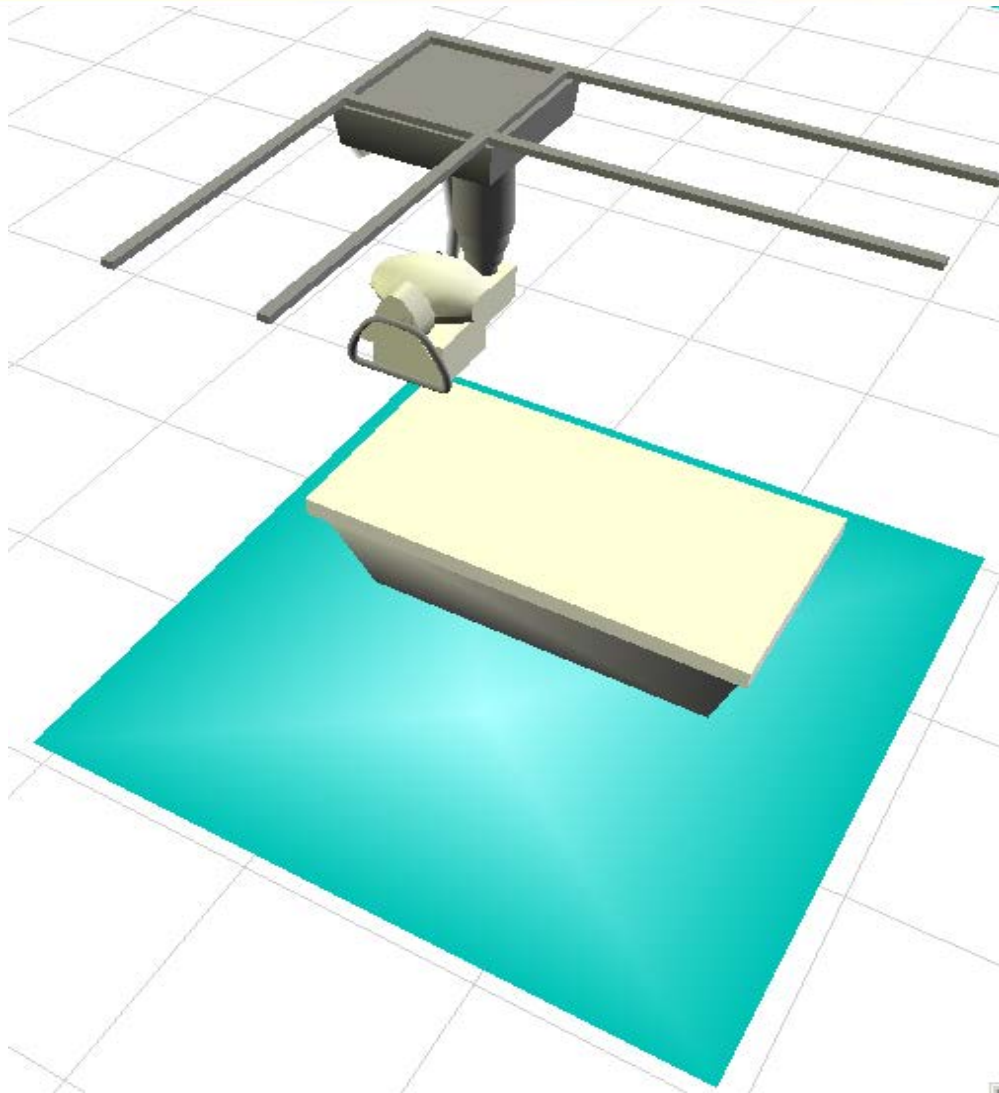
Transport: Ambulance



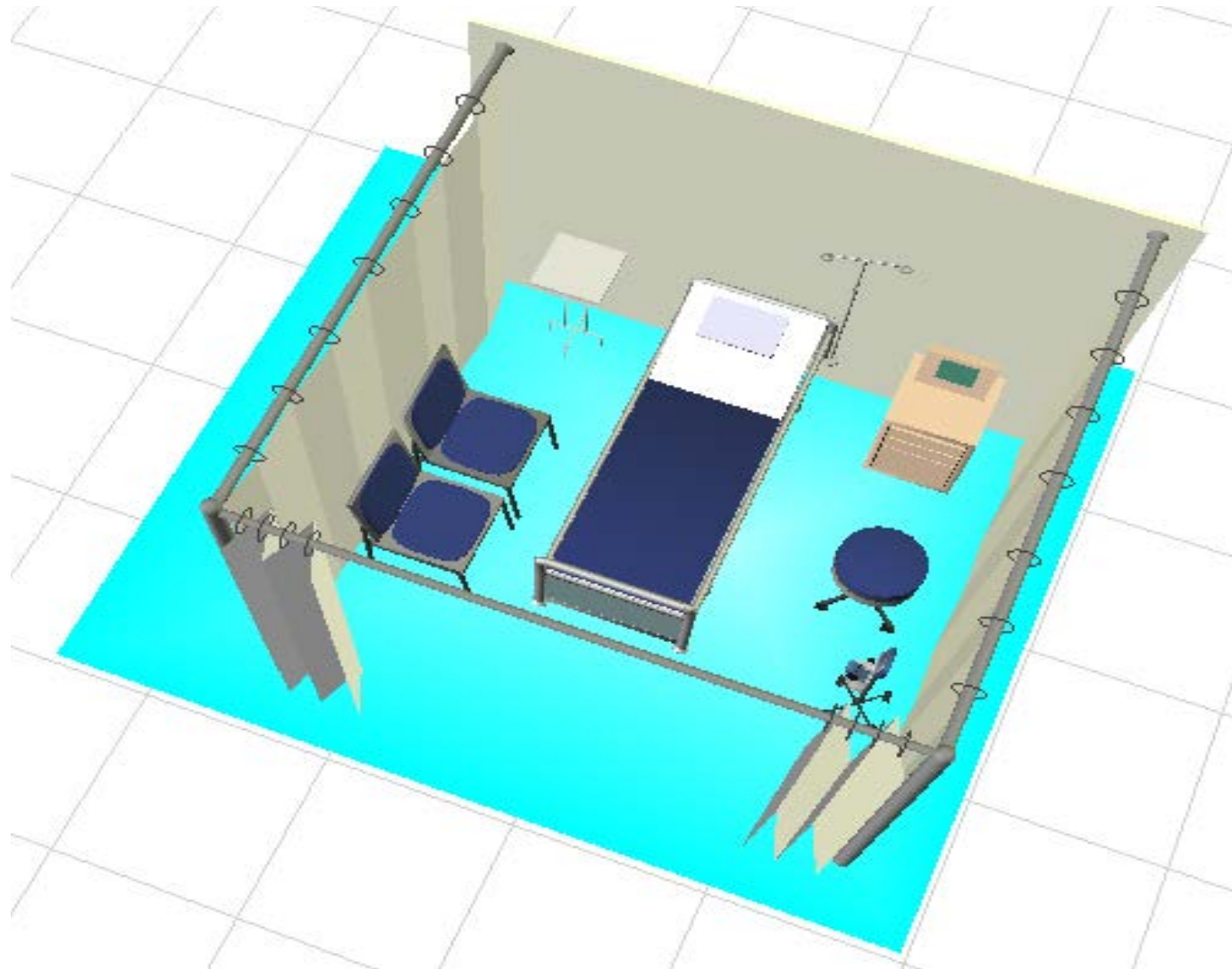
Transport: Helicopter



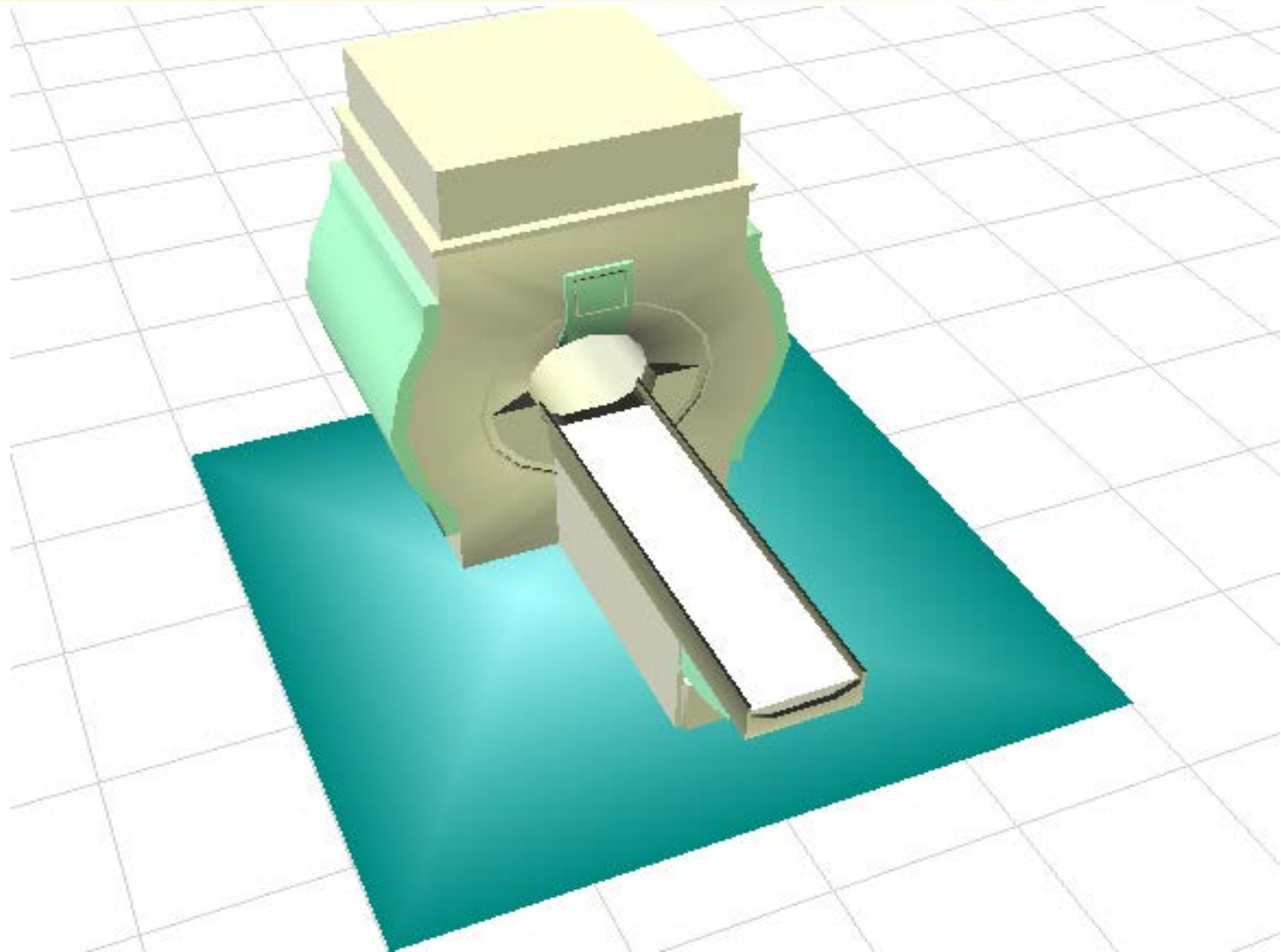
Imaging: XRay



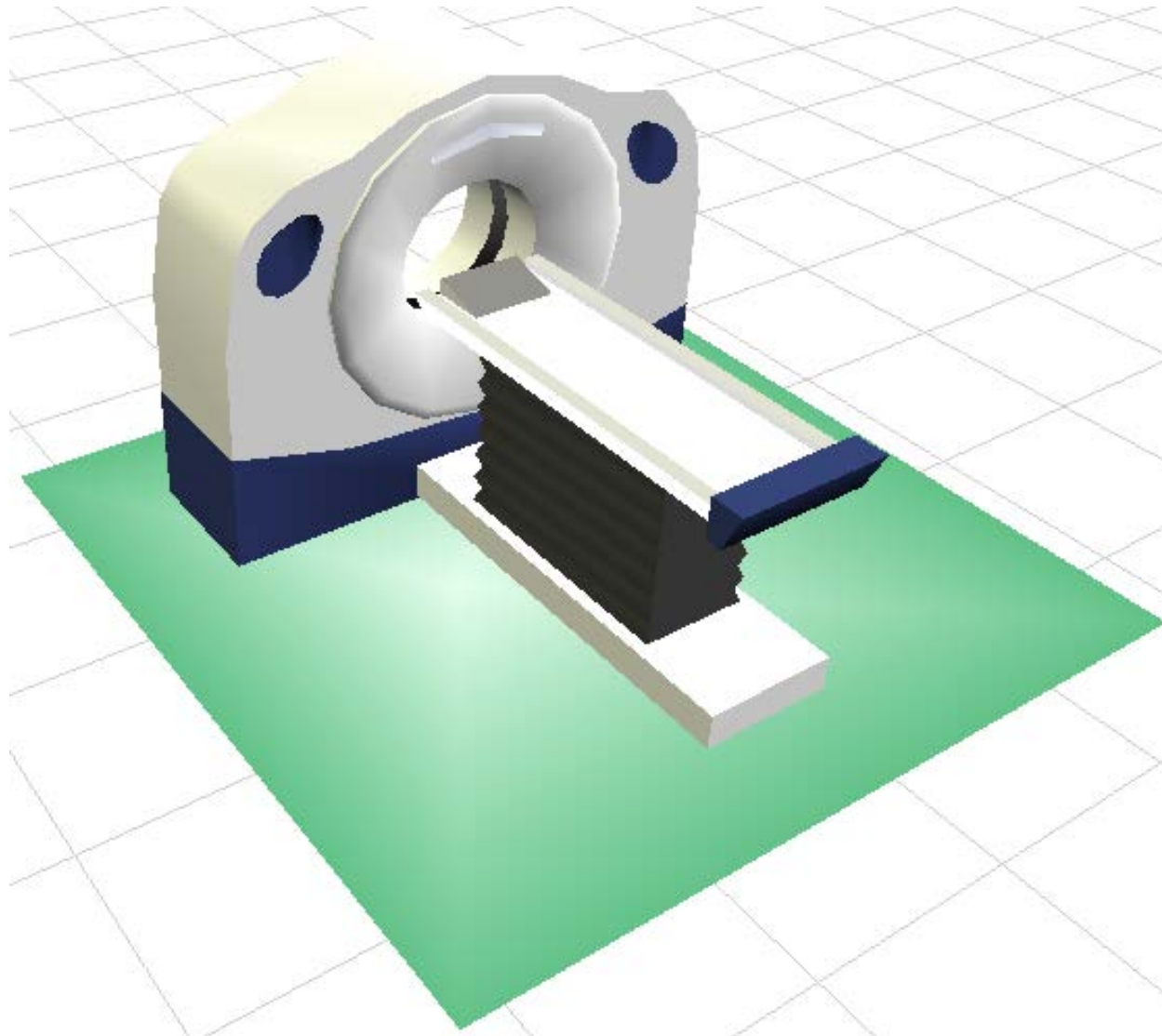
Imaging: Ultrasound



Imaging: MRI



Imaging: CT



Equipment: Pyxis Machine



Object Processing: Lab, Radiology & Pharmacy



ER_Lab_Queue

CurContent: 0

MaxContent: 0

AvgStaytime: 0.0



ER_Lab_Processing

Output: 0

%Idle: 0.0

%Processing: 0.0

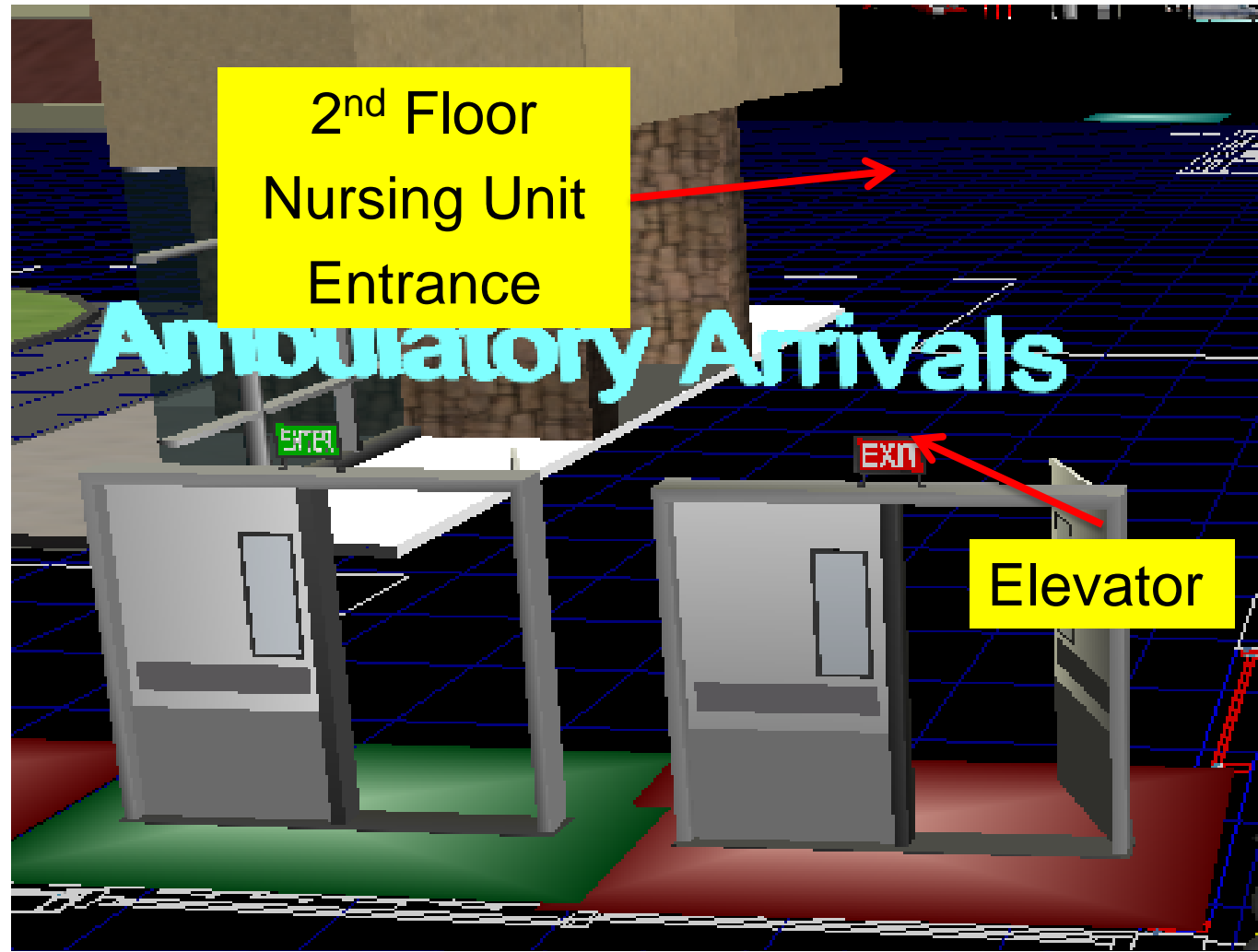


ER_Lab_Exit

Input: 0

Three Patient Exit Destinations

1. Ambulatory Exit
2. Transfer Exit
3. Admission Exit



Simulation Dashboard



Dashboard 1

Patient State Times

- 1. WaitingForActivity (28.7, 13%)
- 2. ReceivingAttention (77.7, 37%)
- 3. ProcessWithoutStaff (4.8, 2%)
- 4. WaitingForRoom (88.4, 42.4%)
- 5. InTransit (2.8, 1.3%)
- 6. WaitingForStaff (6.0, 2.9%)

Patients Processed per Hour of the Day

Length Of Stay (LOS) by Track

Track	LOS (mins)
EMS_Acute_Lab_Rad	152.8
Amb_IntakeCC_Lab_Rad	257.4

Milestone Times

Patient Costs by Track

Track	Average Total Cost per Patient
EMS_Acute_Lab_Rad	145.44
Amb_IntakeCC_Lab_Rad	165.66

Patient Milestones by Track

Track	Average Milestone Completion Times (mins)
EMS_Acute_Lab_Rad	22
Amb_IntakeCC_Lab_Rad	210

Occupancy Levels

Patients In-Process by Track

Track	Number of Patients
EMS_Ac...	5
Amb_IntakeCC_Lab_Rad	28

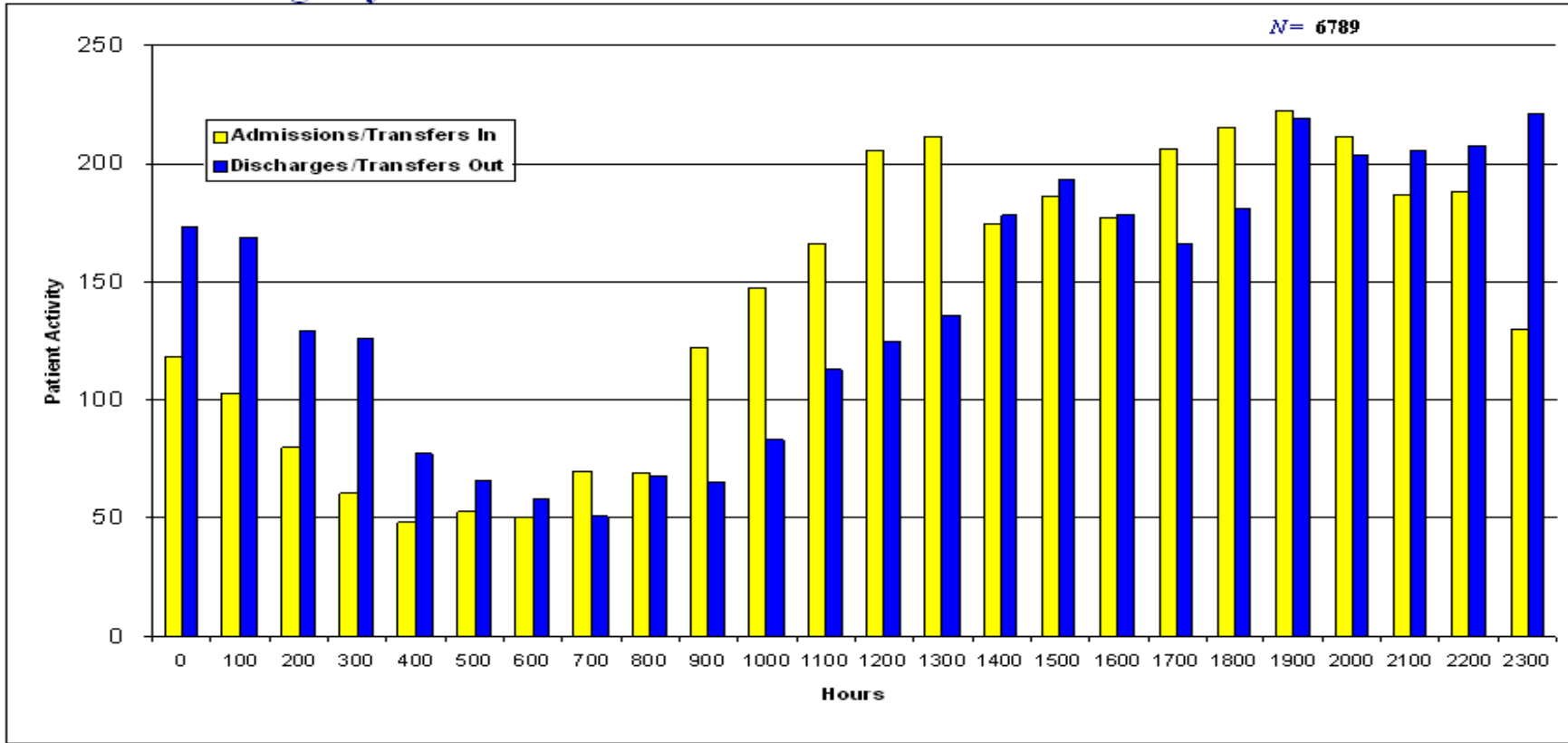
Milestone Completion Times

- 1. Arrival (2.0, 0.1%)
- 2. Triage (15.4, 1.0%)
- 3. Bed Placement (27.8, 1.7%)
- 4. RN Assessment (37.6, 2.3%)
- 5. MD Assessment (137.8, 8.5%)
- 6. Draw Sample (55.7, 3.4%)
- 7. MD Lab Review (70.3, 4.3%)
- 8. Radiology Exam (162.1, 10.0%)
- 9. Radiology Results (168.7, 10.4%)

Arrivals and Discharges



Admits / Discharges / Transfers By Hour Memorial Hermann Katy Hospital 1335500 Emergency Center



Source: HQREGS 01/01/2010 - 01/31/2010

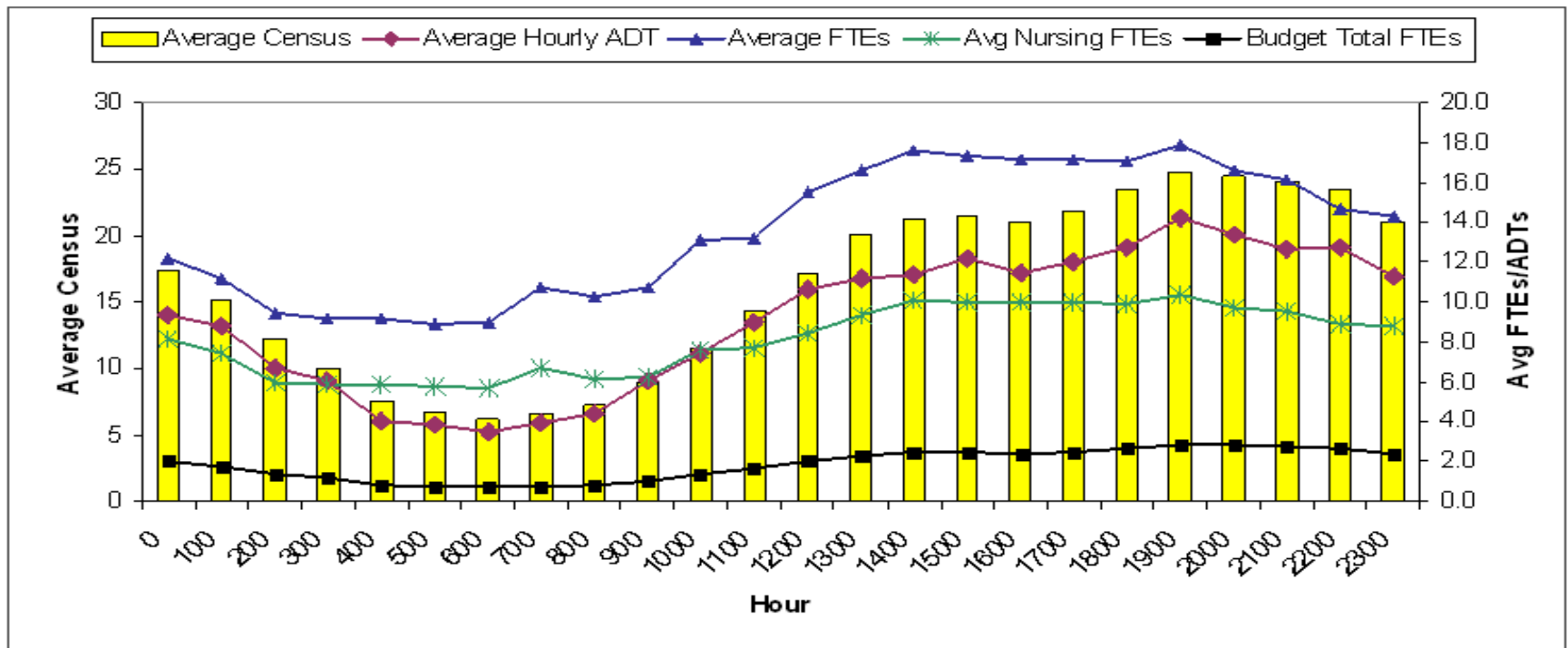
Data Excludes the following: Bed transfers within the same location; Lengths of Stay < 20 minutes

Staff Utilization



Hourly Census vs. Staffing - All Worked Employees

Memorial Hermann Katy Hospital
1335500 Emergency Center



Source: HQREGS 01/01/2010 - 01/31/2010

ADT data excludes the following: Bed transfers within the same location; Lengths of stay < 20 minutes

Nursing FTE data excludes the following: Education, Orientation, and Called-off Pay.

Budget FTE and Total FTEs include ALL employees, including Education/Orientation and Exempt employees. Includes Productive time only.

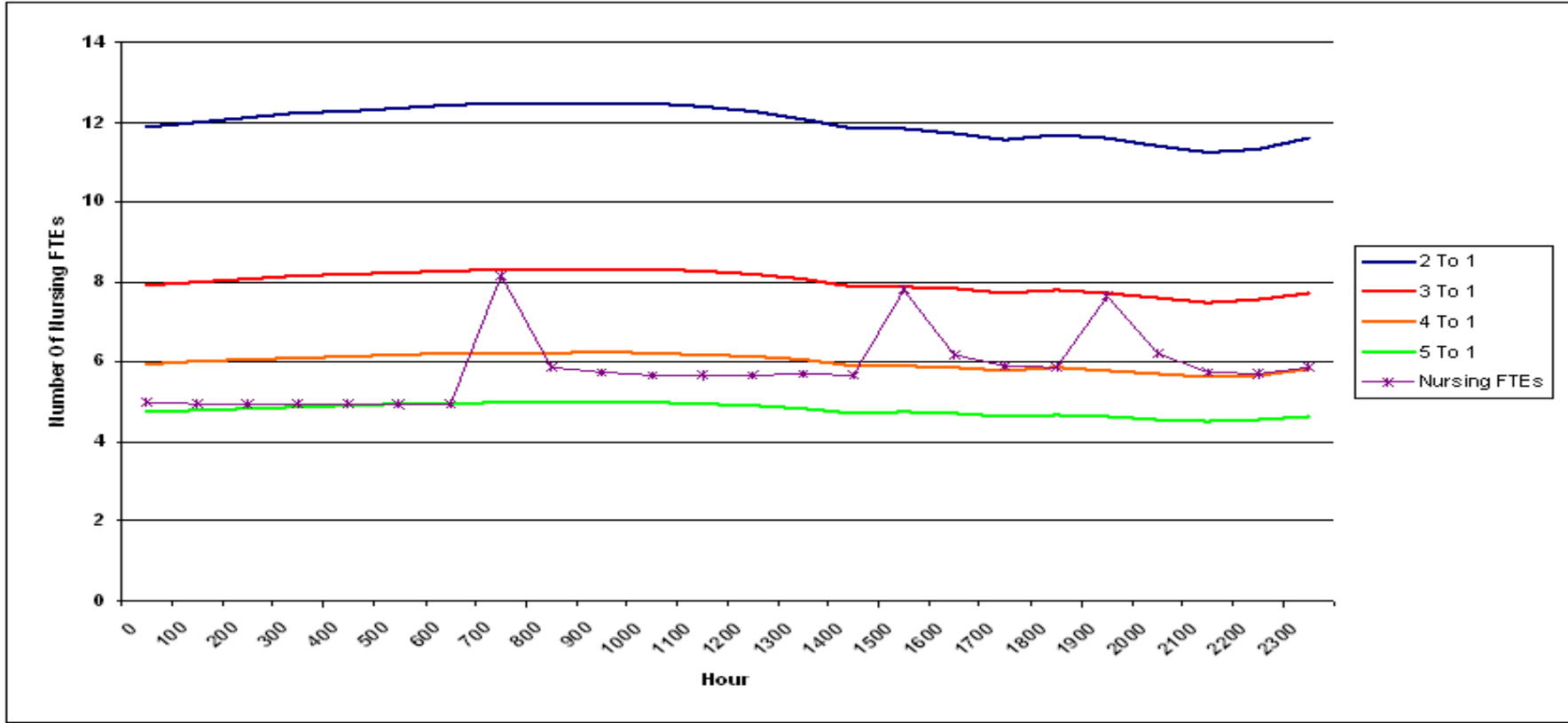
Staff Benchmarks



Average Patient To Nurse Ratios By Hour

Memorial Hermann Katy Hospital

1334110 6th floor

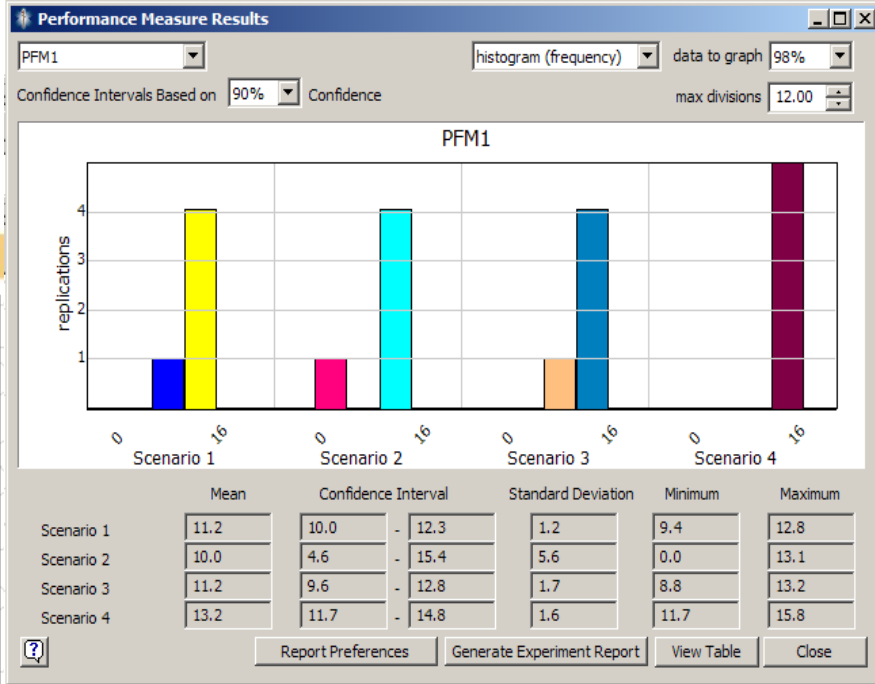


Source: HQREGS 01/01/2010 - 01/31/2010

FTE data excludes the following: Education, Orientation, and Called-off Pay.

Monday, February 22, 2010

Experiment Manager



Experiment Manager

Experimenter | Performance Measures | Advanced Functions

Settings

Warmup End Time: 0.00 | Number of Replications: 5.00

Simulation End Time: 1440 | Save output files for each replication

Variables

Number of Variables: 2 | Number of Scenarios: 4

Experiment Variables	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Variable 1: Dressing Rooms	1	2	2	3
Variable 2: Patients per Hour	2	2	6	6

Experiment Manager

Experimenter | Performance Measures | Advanced Functions

Add | Remove | View Results

PFM1

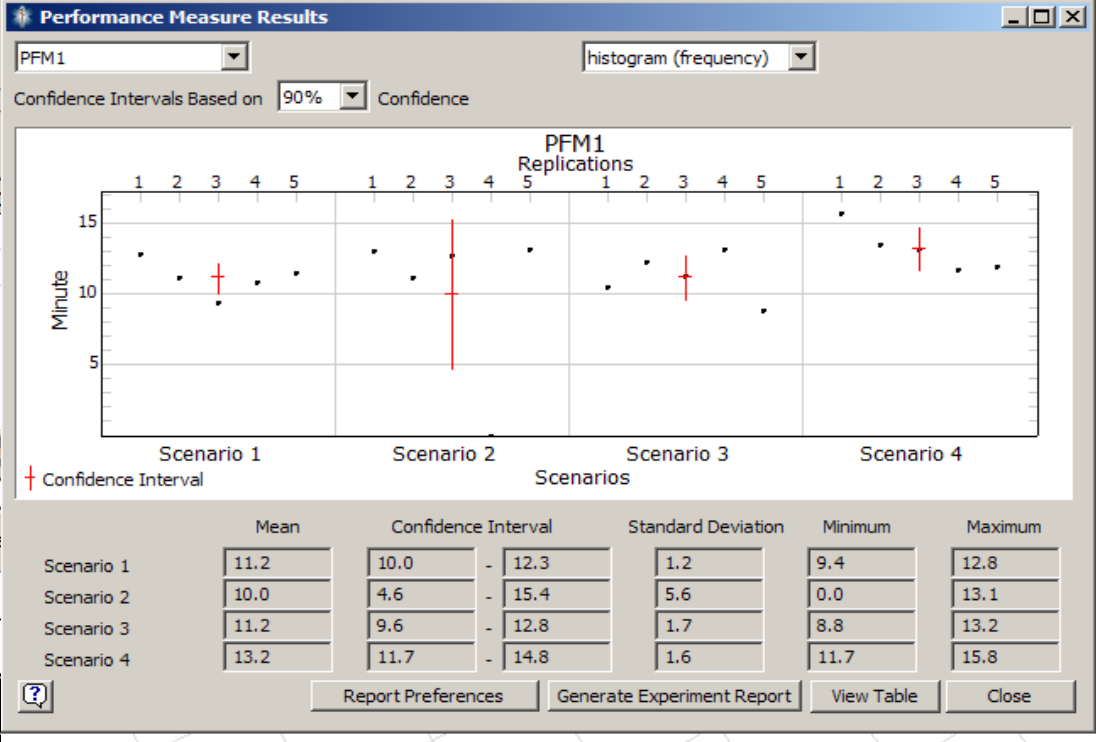
Performance Measure Name: PFM1

Performance Measure Definition: Average Length of Stay (LOS) Per Patient \nTrack: "ForAllTracks"

Text to Display for the Performance Measure's Units: Minute

Replication: 5 | Scenario: 4

Start Experiment | Suspend Draw | Apply | OK



Milestones Downloaded to Excel



Flexsim Simulation Sample Time Distributions in Minutes

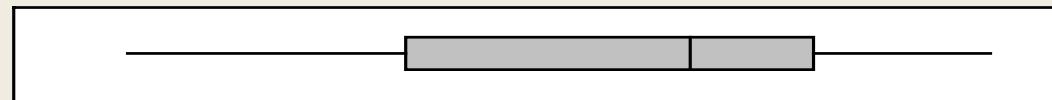
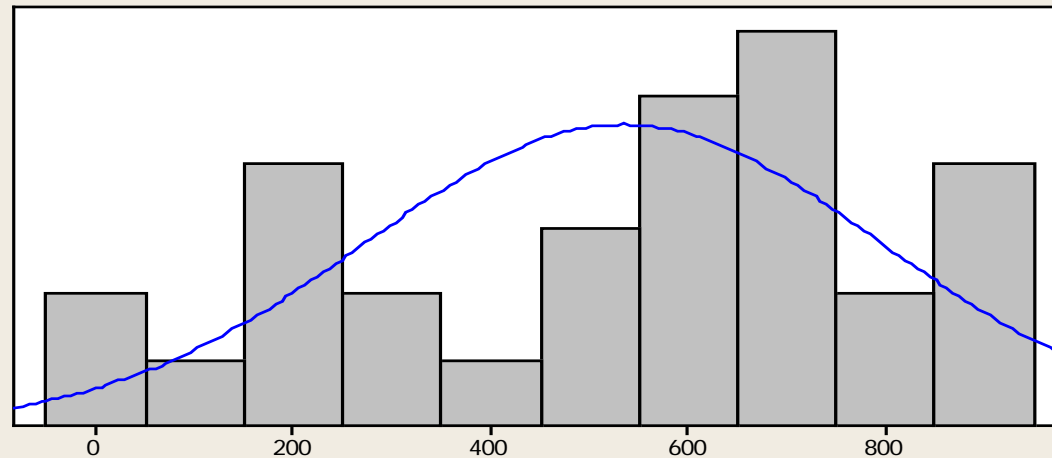
PatientID Track	1 Amb_IntakeCC	109 Amb_IntakeCC	4 Amb_Acute	129 Amb_Acute	6 EMS_Acute	47 EMS_Acute	41 EMS_IntakeCC	467 EMS_IntakeCC
Milestones:								
Arrival	0	735	0	1,193	-	-	-	-
Quick Register	3	738	2	1,195	-	-	-	-
Begin QL	4	742	3	1,202	-	-	-	-
Triage	-	-	-	-	9	10	10	8
InBed1	16	888	9	1,579	10	10	136	296
RN Assessment	25	896	15	1,589	20	17	144	304
Medical Screening	42	1,030	31	1,705	-	70	-	367
MD Initial Exam	51	1,121	58	1,812	-	136	-	405
Draw Sample	-	1,146	-	1,835	-	166	-	428
InBed2	113	-	-	-	-	-	-	-
MD Lab Review	173	1,357	186	2,127	-	265	-	514
Provider Intervention	298	1,631	-	2,259	-	-	-	551
RN Intervention	-	-	-	-	-	-	-	-
Care Complete	298	1,631	-	2,259	-	361	-	551
Imaging:								
MRI Procedure	-	-	-	1,948	-	-	-	-
Xray Procedure	103	-	94	-	-	-	-	-
CT Procedure	-	1,220	-	-	-	-	-	-
US Procedure	-	-	-	-	-	-	-	482
Radiology Results	110	1,228	102	1,957	-	-	-	490
Radiology Read	148	1,342	147	2,036	-	-	-	526
Exit Destinations:								
Admitted	-	-	-	-	-	-	-	760
Discharge	321	1,653	-	-	-	-	-	-
Transfer	-	-	-	-	-	388	-	-
LWBS	-	-	-	-	31	-	155	-
AMA	-	-	266	-	-	-	-	-
Expired	-	-	-	2,304	-	-	-	-
TotalLOS (mins)	321	1,653	266	2,304	31	388	155	760
TotalLOS (hrs)	5.4	27.6	4.4	38.4	0.5	6.5	2.6	12.7

36

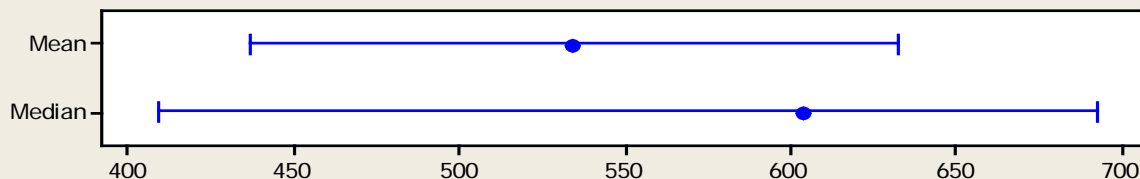
Minitab Analysis – Scenario 1: What is the current state?

Scenario 1 – Exiting Model As Is

Summary for TotalLOS



95% Confidence Intervals



Anderson-Darling Normality Test

A-Squared 0.72
P-Value 0.055

Mean 534.24
StDev 261.57
Variance 68419.68
Skewness -0.504179
Kurtosis -0.867588
N 30

Minimum 32.58
1st Quartile 315.10
Median 603.45
3rd Quartile 726.96
Maximum 904.91

95% Confidence Interval for Mean
436.57 631.92

95% Confidence Interval for Median
408.97 692.64

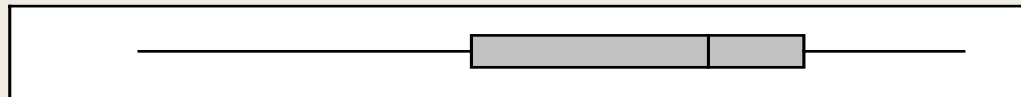
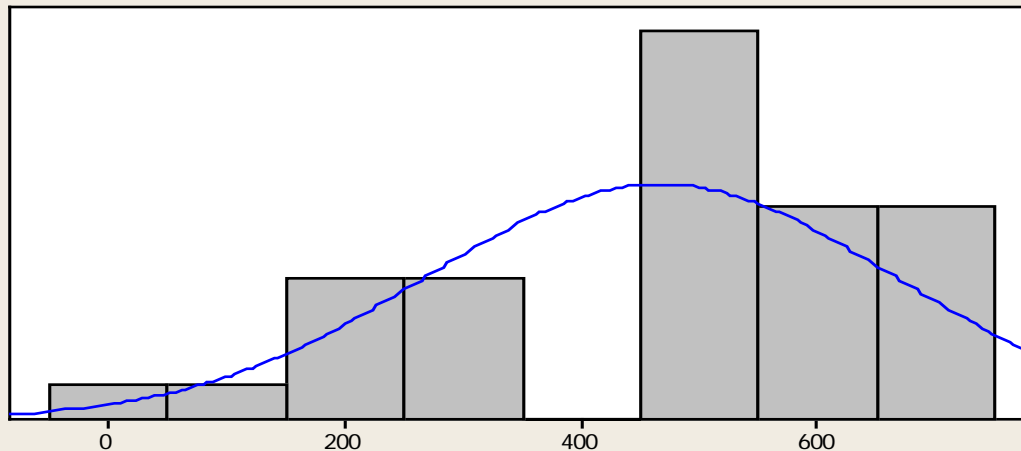
95% Confidence Interval for StDev
208.32 351.63

Minitab Analysis - Scenario 2: How significant of a shift takes place?

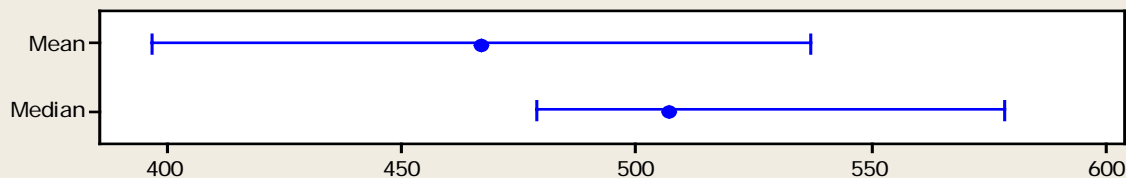


Scenario 2 – Add 2 Intake Beds and 1 full time Intake Nurse

Summary for TotalLOS



95% Confidence Intervals

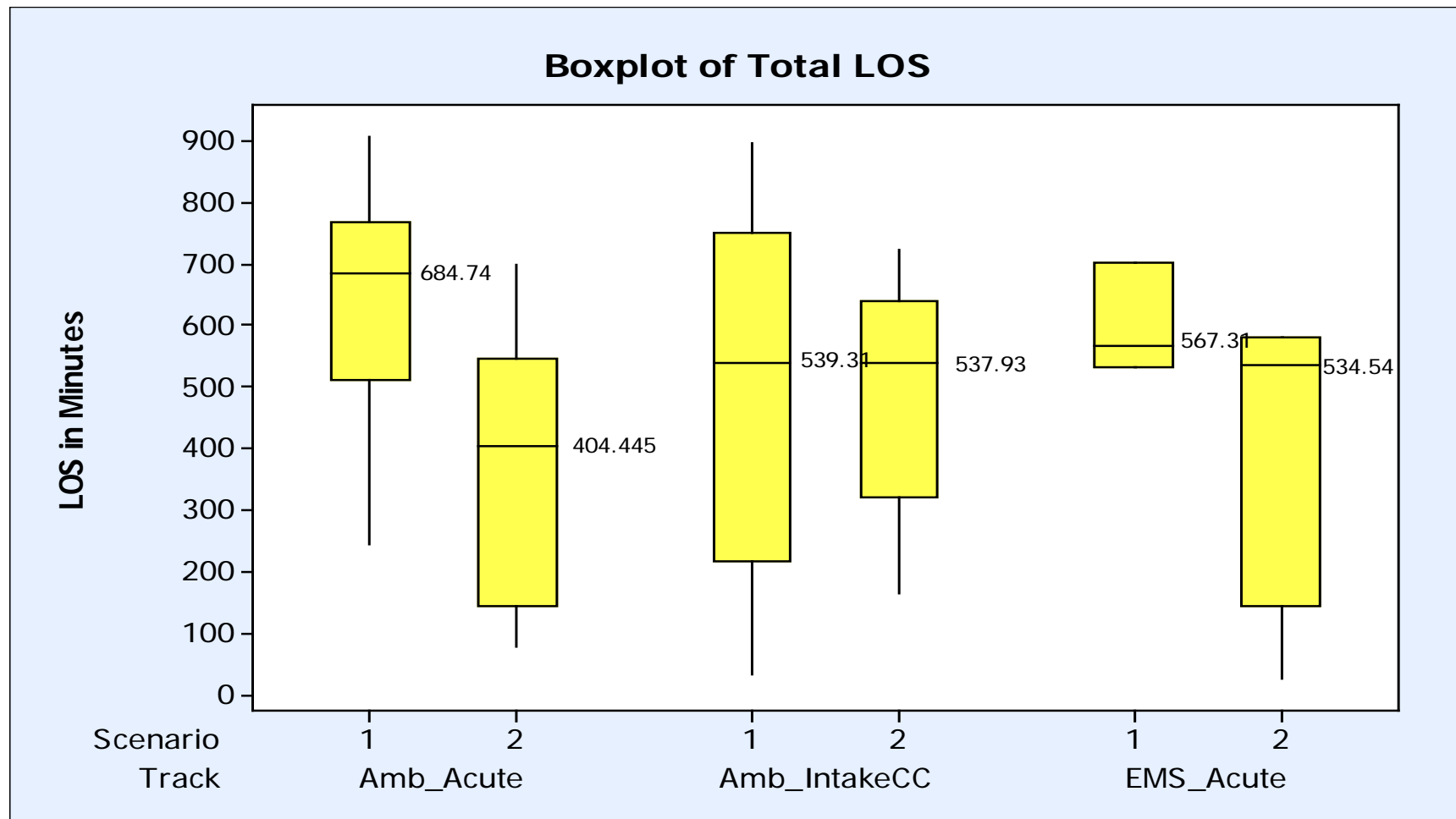


Anderson-Darling Normality Test	
A-Squared	1.10
P-Value	0.006
Mean	466.88
StDev	198.04
Variance	39221.23
Skewness	-0.703970
Kurtosis	-0.499184
N	33
Minimum	26.39
1st Quartile	307.35
Median	506.96
3rd Quartile	586.83
Maximum	723.51
95% Confidence Interval for Mean	396.65 537.10
95% Confidence Interval for Median	478.50 577.89
95% Confidence Interval for StDev	159.26 261.95

Box Plots of Length of Stay: Would we “feel” the proposed change?

Scenario 1 – Existing Model As Is

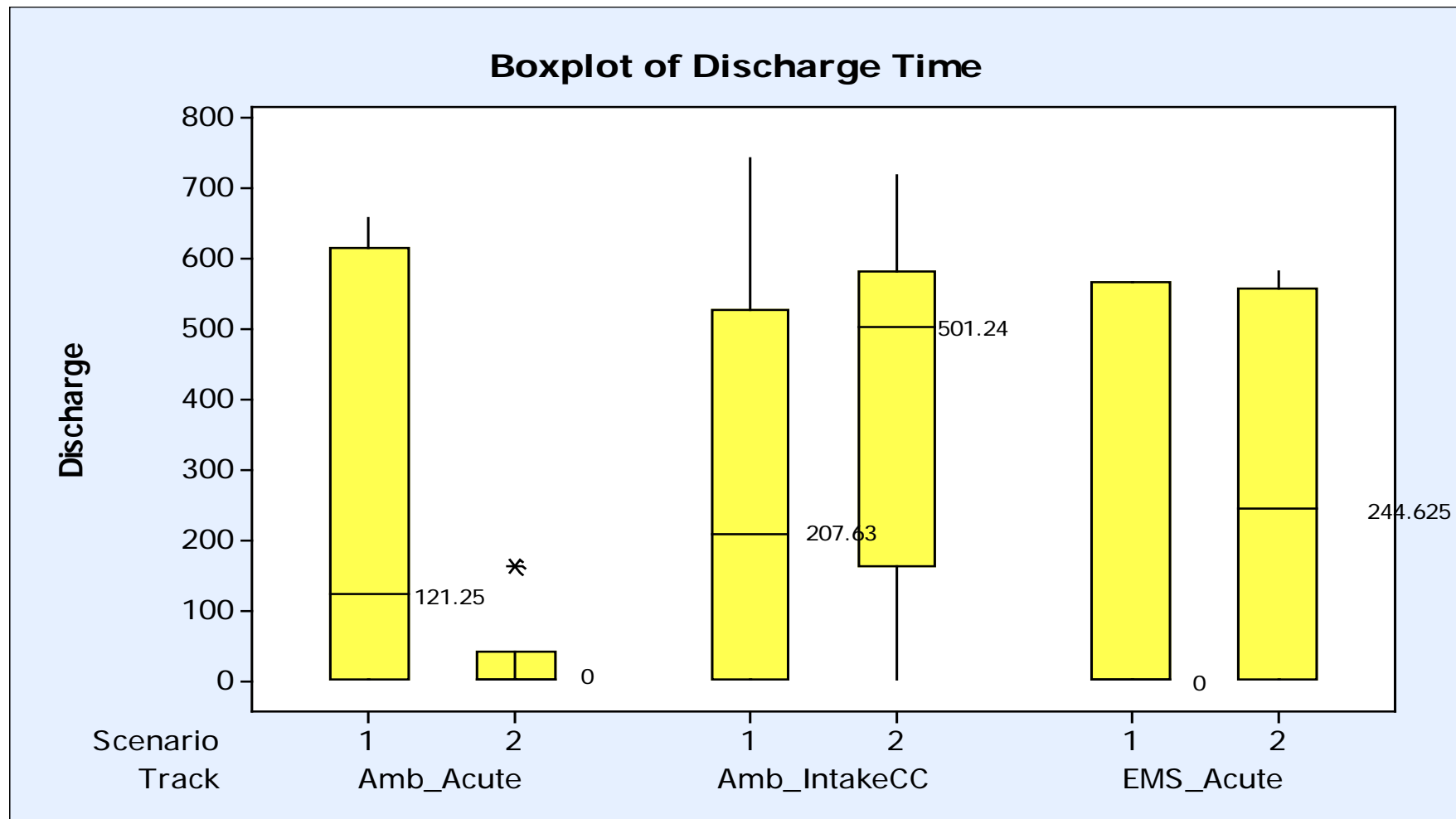
Scenario 2 – Add 2 Intake Beds and 1 Fulltime Intake Nurse



Box Plots of Discharged Patients: Would we “feel” the proposed change?

Scenario 1 – Exiting Model As Is

Scenario 2 – Add 2 Intake Beds and 1 Fulltime Intake Nurse



Box Plots of Admitted Patients: Would we “feel” the proposed change?

Scenario 1 – Exiting Model As Is

Scenario 2 – Add 2 Intake Beds and 1 Fulltime Intake Nurse

