This presenter has nothing to disclose

Academic Principles for Improving ED operations

Jody Crane, MD, MBA, FACEP
Chief Clinical Officer, TeamHealth EM
Jody_crane@TeamHealth.com

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Outline

- Queuing theory and Lean Principles for Improvement
- Lean Flow

- The Theory of Constraints – A Systems Perspective

Academics

- Queuing Theory

What Causes Waiting?

- Excessive Utilization
- Variation

Using Queueing Theory to Increase the Effectiveness of Emergency Department Provider Staffing

Linda V. Green, PhD, João Soares, PhD, James F. Giglio, MD, Robert A. Green, MD

Abstract

Objectives: Significant variation in emergency department (ED) patient arrival rates necessitates the adjustment of staffing patterns to optimize the timely care of patients. This study evaluated the effectiveness of a queueing model in identifying provider staffing patterns to reduce the fraction of patients who leave without being seen.

Methods: The authors collected detailed ED arrival data from an urban hospital and used a Lag SIPP queueing analysis to gain insights on how to change provider staffing to decrease the proportion of patients who leave without being seen. The authors then compared this proportion for the same 39-week period before and after the resulting changes.

Results: Despite an increase in arrival volume of 1,078 patients (6.3%), an average increase in provider hours of 12 hours per week (3.1%) resulted in 258 fewer patients who left without being seen. This represents a decrease in the proportion of patients who left without being seen by 22.9%. Restricting attention to a four-day subset of the week during which there was no increase in total provider hours, a reallocation of providers

Agner Krarup Erlang

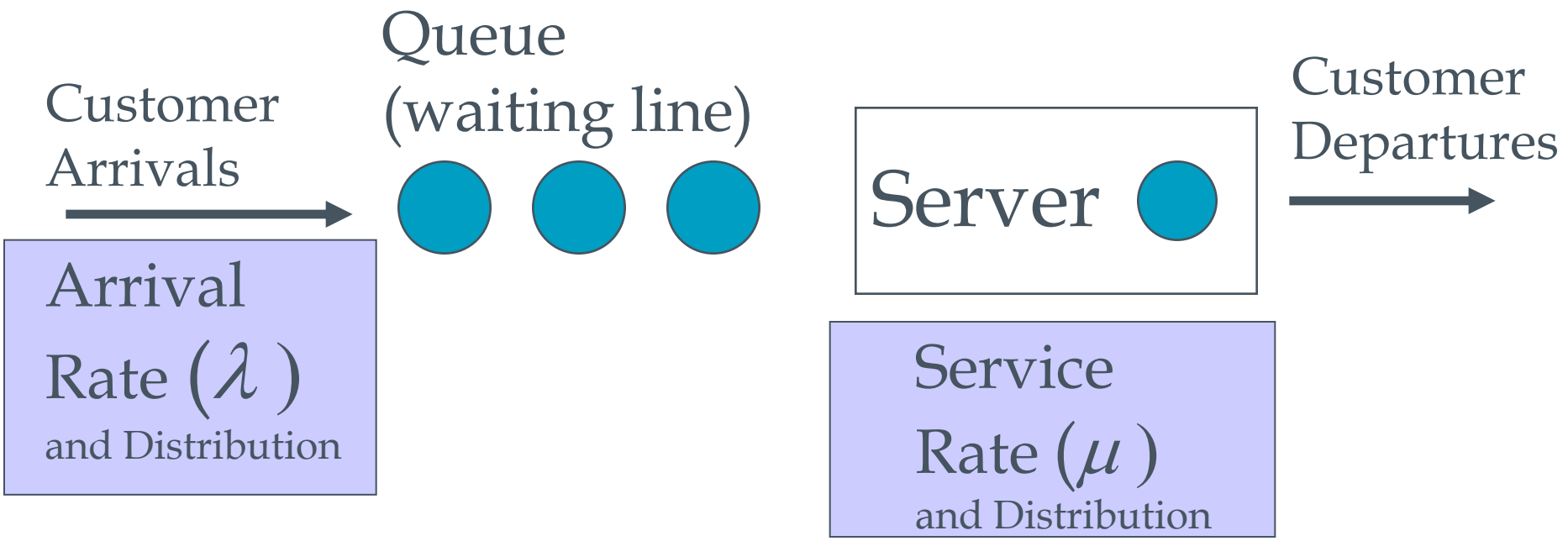
Copenhagen Telephone Company (KTAS), 1908

"Solution of some Problems in the Theory of Probabilities of Significance in Automatic Telephone Exchanges," 1917

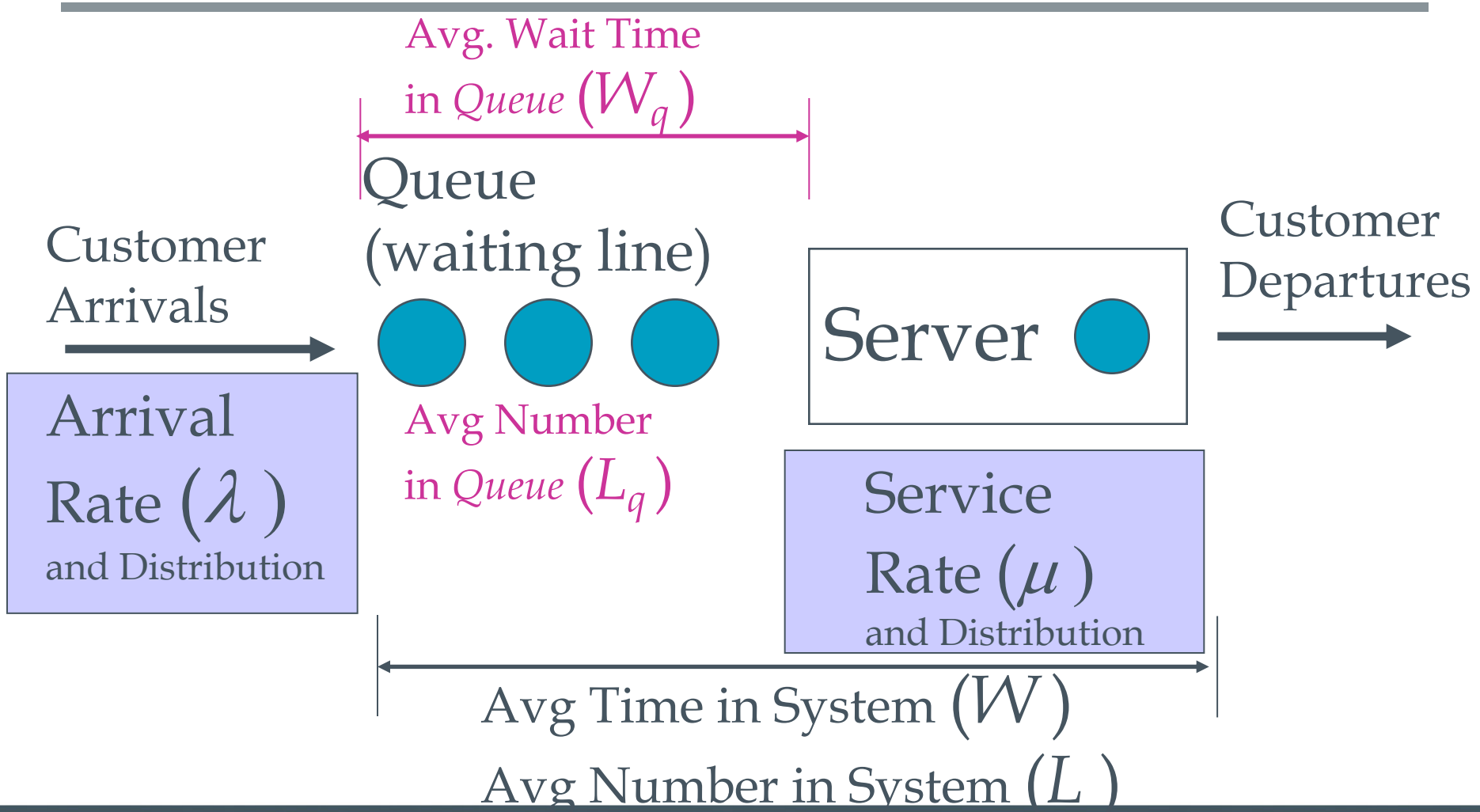
A Simple Queue

A Simple Queue

A Simple Queue



A Simple Queue



Triage Example 1

Suppose we have a triage operation staffed by a single nurse. Patients arrive and wait in the waiting area if the triage nurse is busy triaging other patients. When a patient is seen by the triage nurse, the triage activity occurs in a single encounter.

Data was gathered and, on average, **6** patients arrive per hour. The average time it takes to triage a patient is **12** minutes.

So, will there be any waiting? YES!

Triage Example 2

Suppose we have a triage operation staffed by a single nurse. Patients arrive and wait in the waiting area if the triage nurse is busy triaging other patients. When a patient is seen by the triage nurse, the triage activity occurs in a single encounter.

Data was gathered and, on average, **4** patients arrive per hour. The average time it takes to triage a patient is 12 minutes **(again, a "service rate" of 5 patients/hour).**

So, will there be any waiting? It Depends!

Sigma ED - Ideal Triage

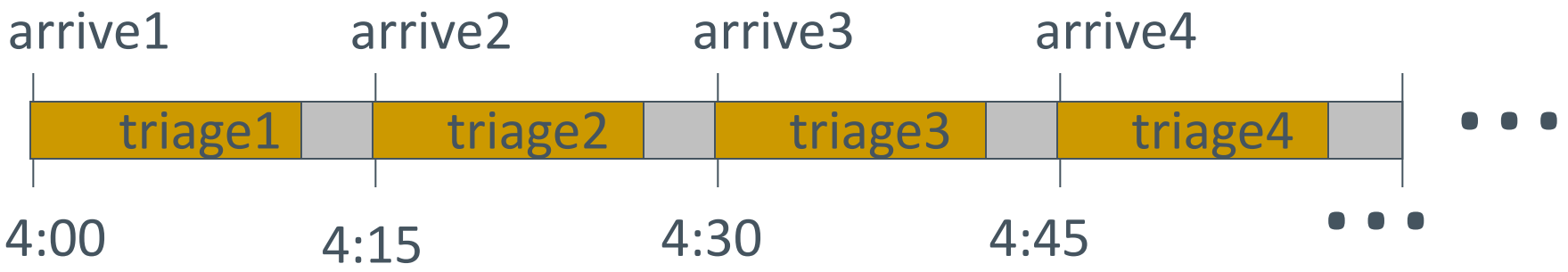
On average, 4 patients arrive per hour.

Assume 1 patient arrives *every* 15 minutes.

The time it takes the nurse to triage a patient averages 12 minutes (can triage 5 per hour).

Assume *exactly* 12 minutes per patient.

Sigma ED - Ideal Triage

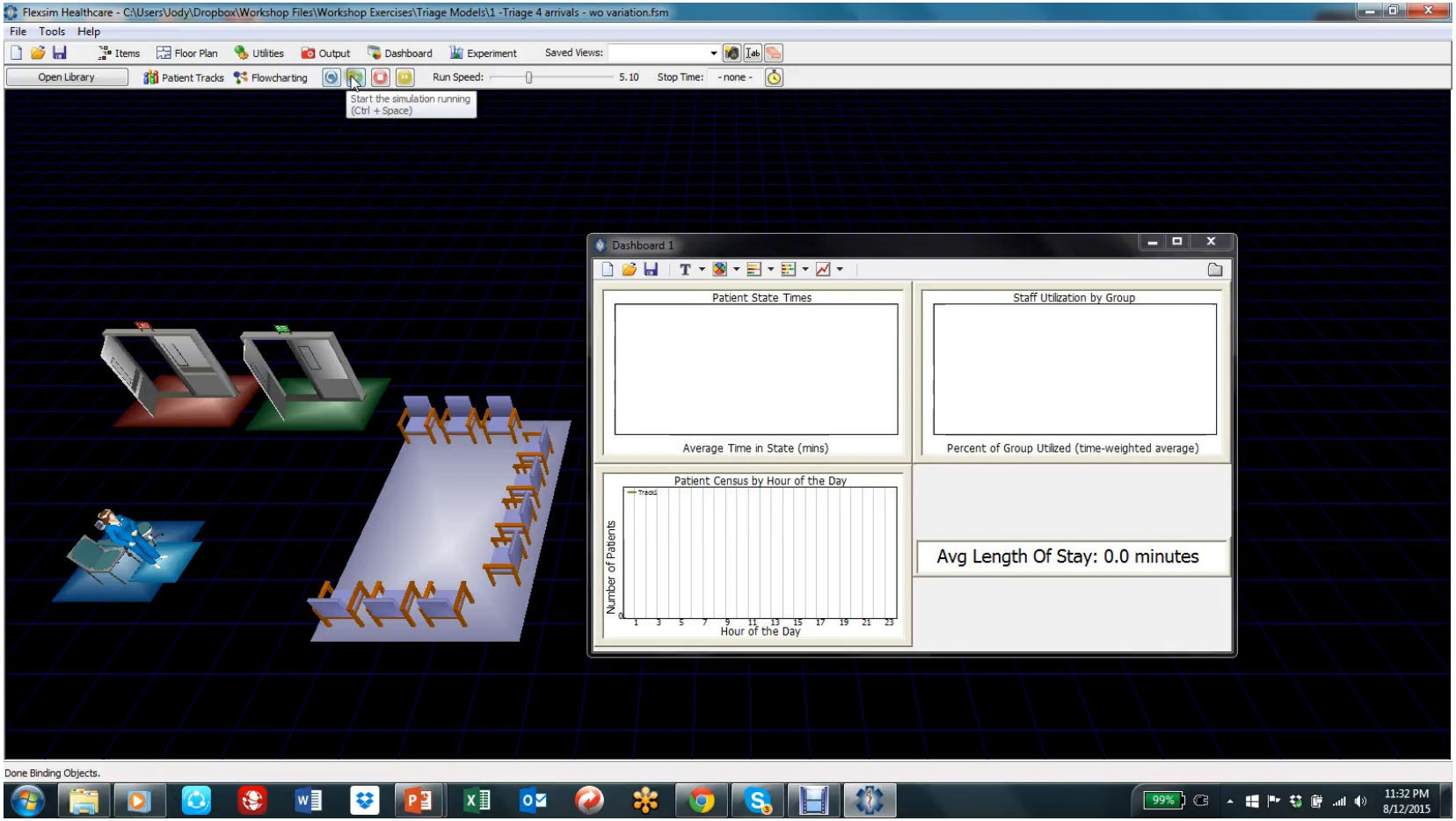


- The nurse and patient arrive at 4pm
- The first triage encounter lasts exactly 12 min
- The nurse has exactly 3 min of idle time
- The next patient arrives at exactly 4:15
- And so on…

Sigma ED - Ideal Triage

QueueCalc

Sigma ED - Ideal Triage



Sigma ED Triage – Variation

On average, 4 patients arrive per hour.

Assume 1 ~~patient arrives *every* 15 minutes~~s.

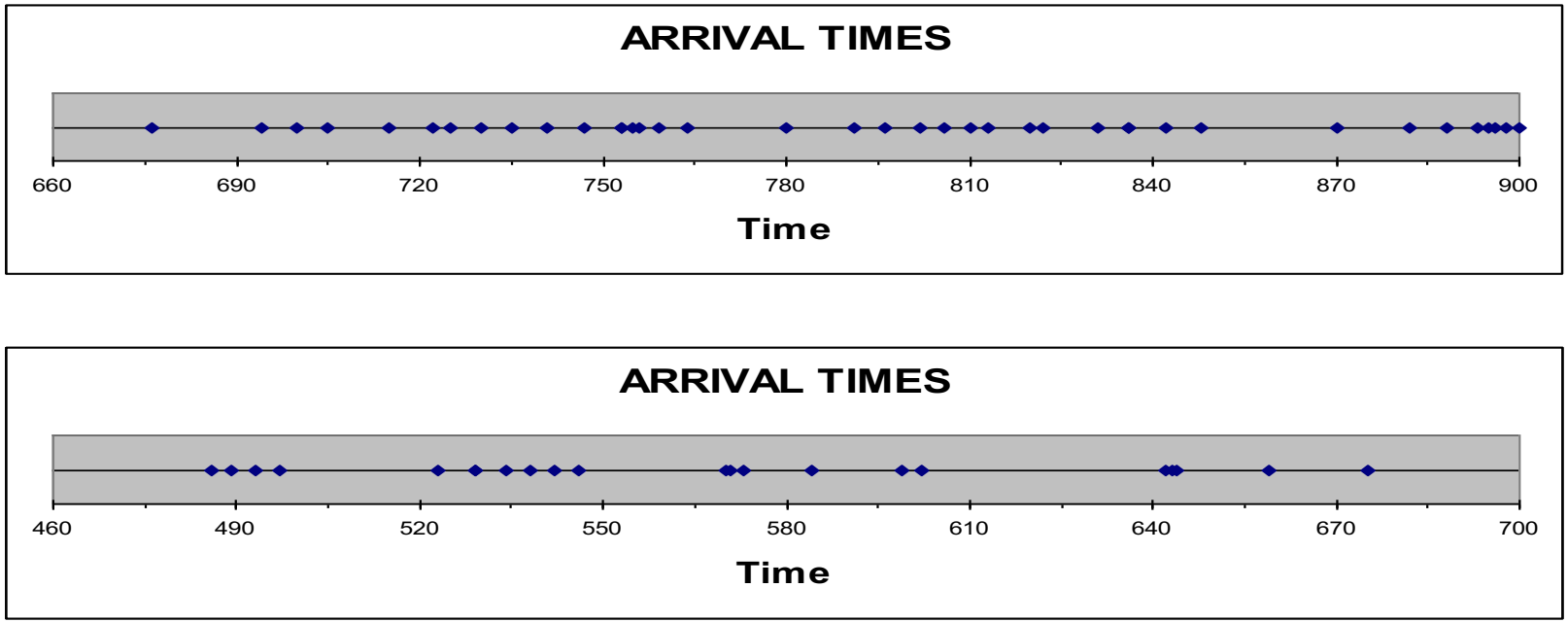
random arrival process.

The time it takes the nurse to triage a patient averages 12 minutes (can triage 5 per hour).

Assume ~~e*xactly* 12 minutes per patient~~.

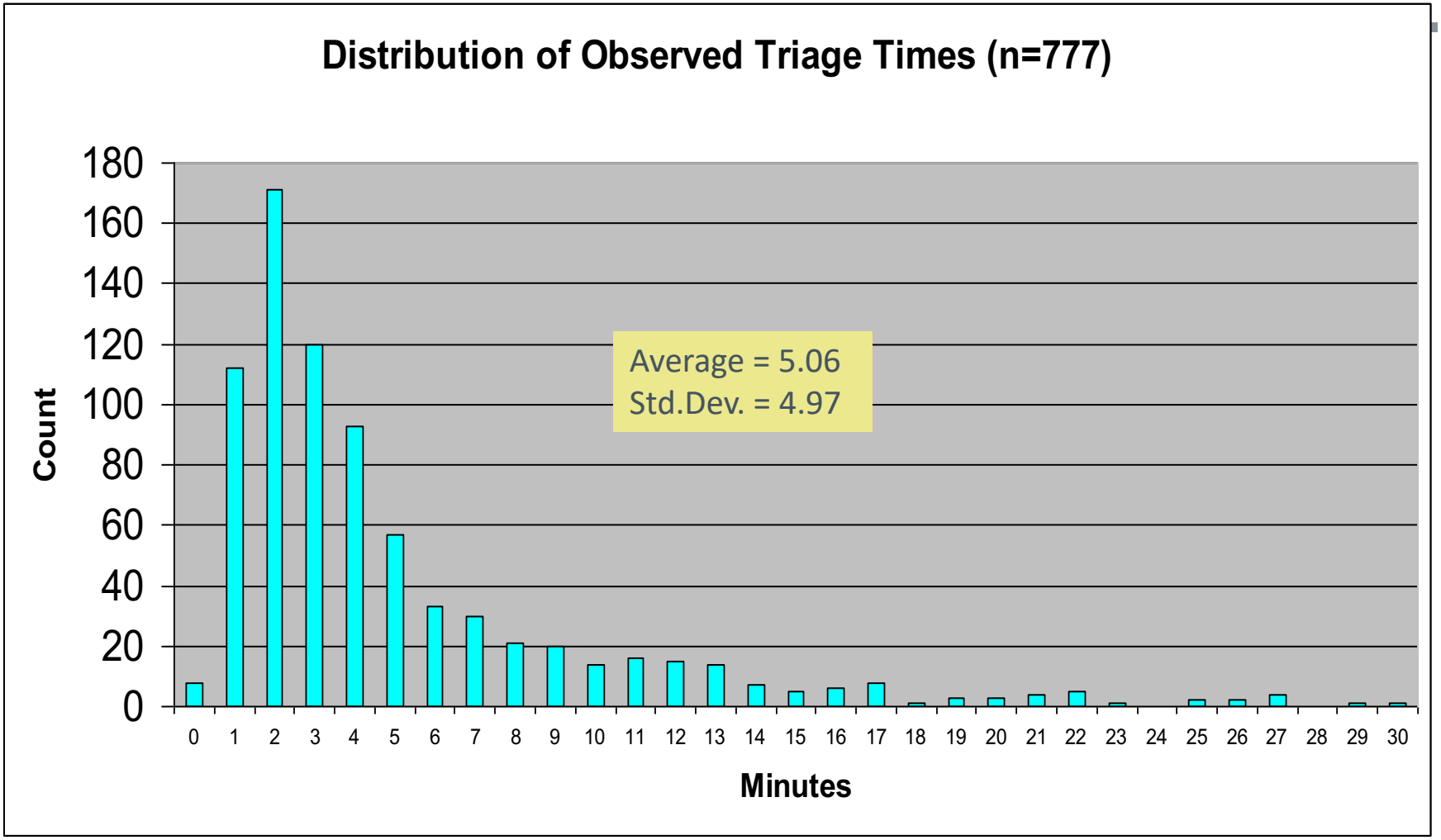
variation around service times

Arrival data from a real ED



Arrival data from a California hospital. Mondays, 2pm-6pm.

Distribution of Actual ED Triage Times.



Sigma ED Triage – Variation

On average, 4 patients arrive per hour.

Assume 1 ~~patient arrives every 15 minutes~~.

random arrival process.

The time it takes the nurse to triage a patient averages 12 minutes (can triage 5 per hour).

Assume ~~exactly 12 minutes per patient~~.

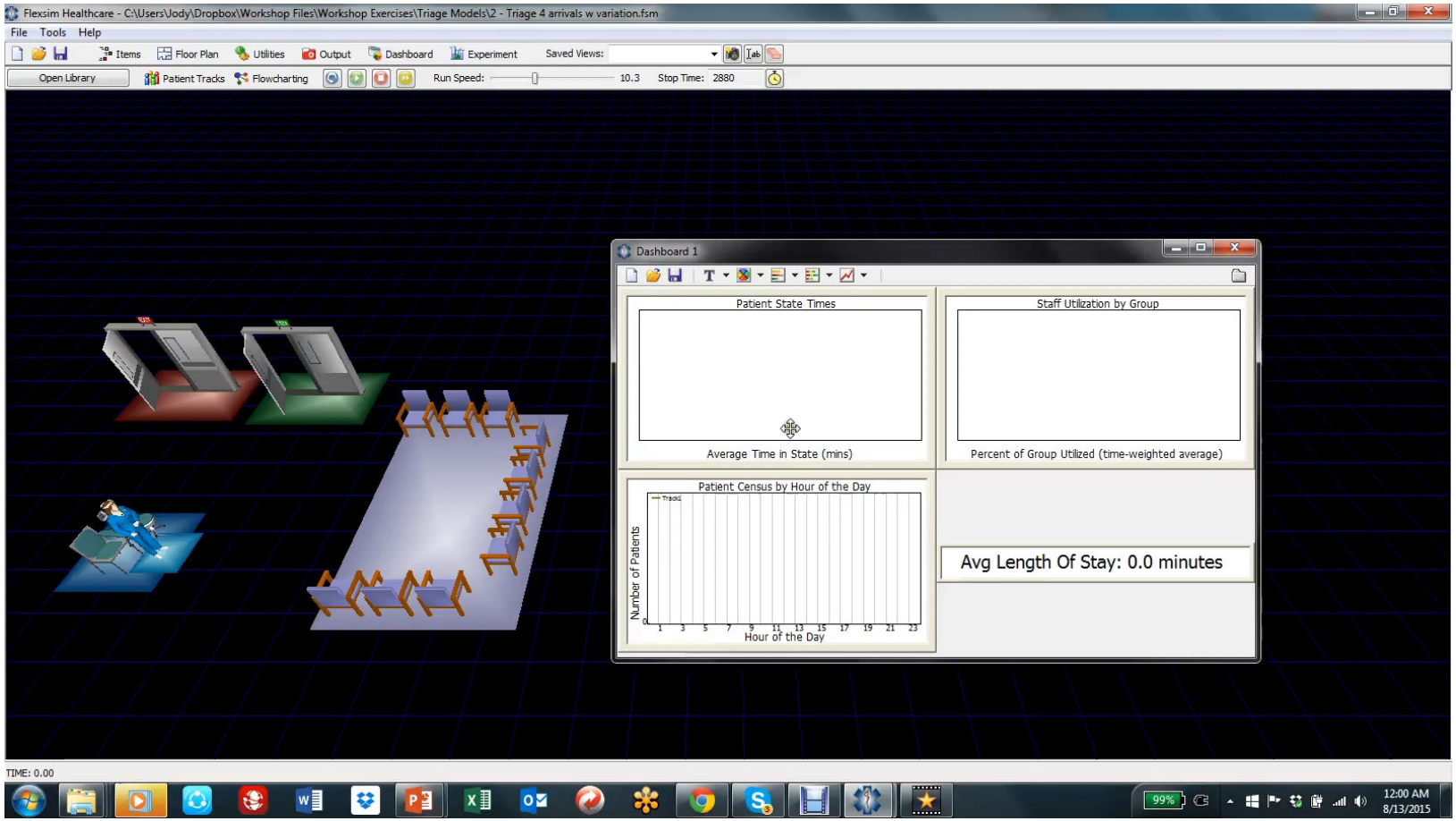
variation around service times

Will there be waiting, and if so, *how much*?

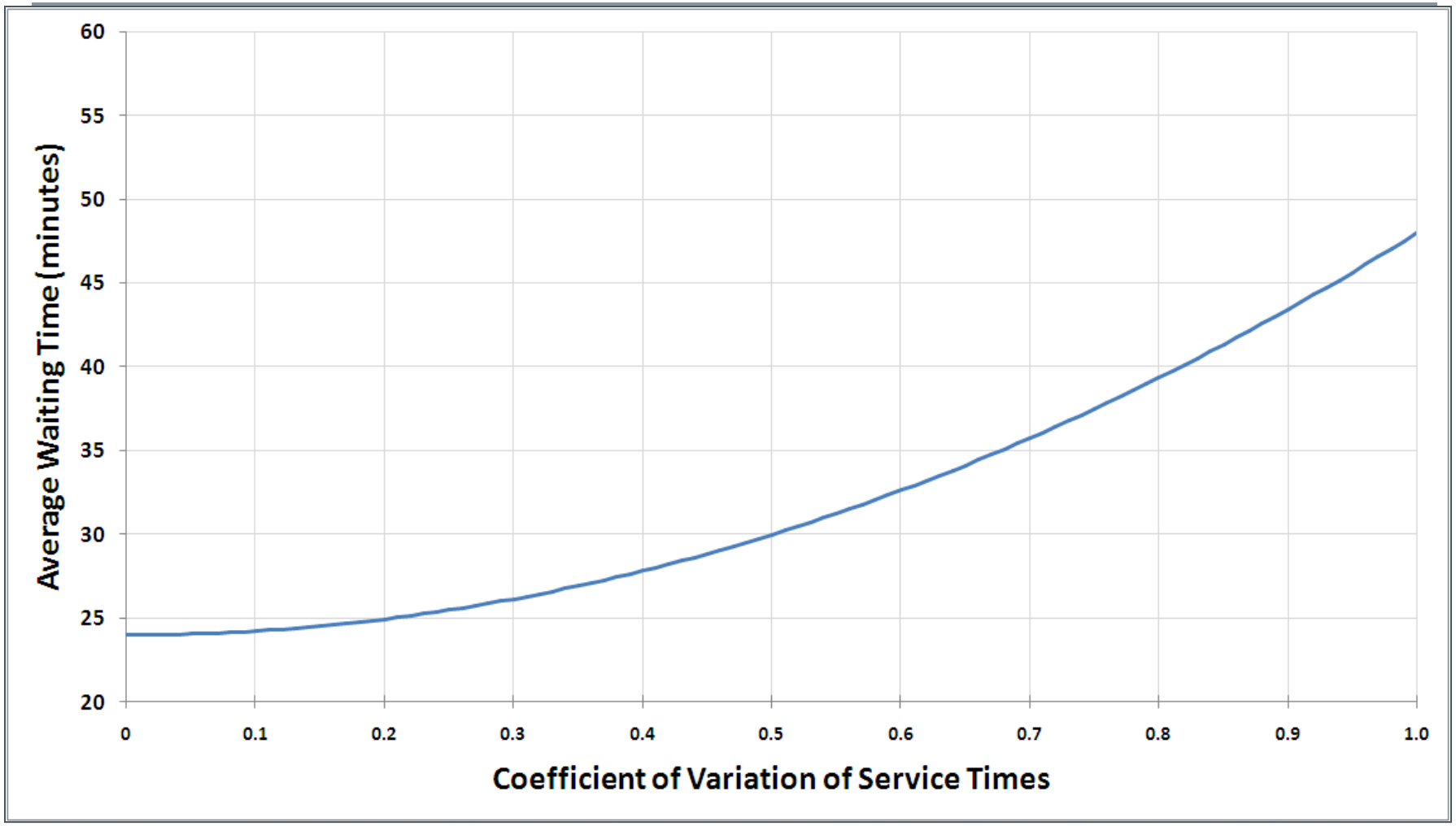
Sigma ED - Ideal Triage

QueueCalc

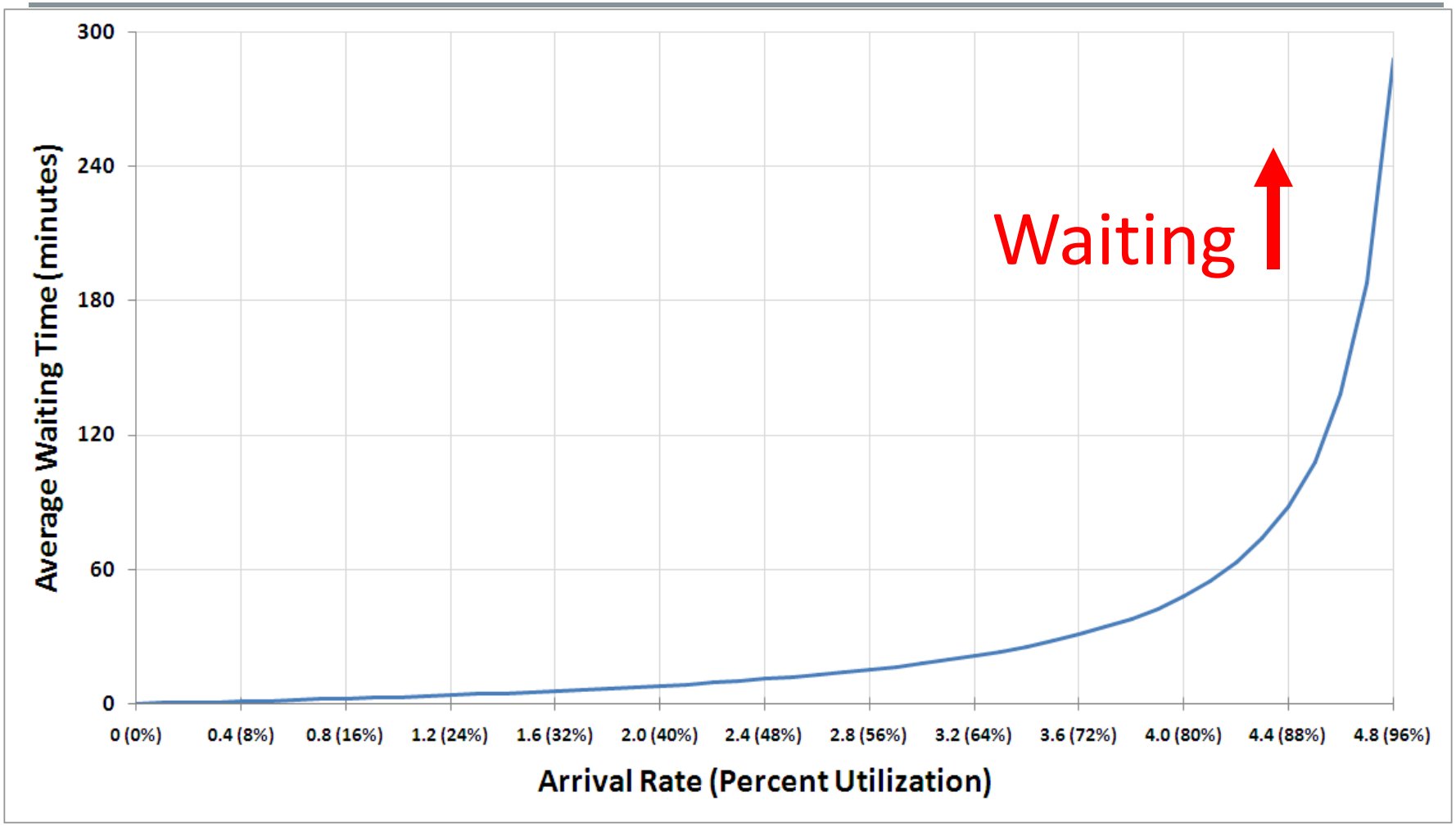
Sigma ED - Ideal Triage



As Server *Variation* Increases…



As *Utilization* Increases…



Academics

- Lean Flow

Achieving Lean Flow

Principle - To reduce "flow time" through an individual queue, you must do one of the following:

- Reduce average rate of arrivals (rationalize, offload)
- Reduce variation in time between arrivals (standardize)
- Reduce average service times (eliminate waste)
- Reduce variation in service times (standardize)
- Add server capacity or change the *timing* of server capacity (align)

Affecting the Arrival Rate…

SCOTTSDALE HEALTHCARE | fastERtimes.org — Full Service, World-Class Emergency Care 24/7

Current Emergency Room (ER) Wait Times

Osborn ER 7400 E. Osborn Road Scottsdale, AZ 85251	2 min.	Directions | Register
Shea Main ER 9003 E. Shea Boulevard Scottsdale, AZ 85260	No Wait	Directions | Register
Shea Kids ER 9003 E. Shea Boulevard Scottsdale, AZ 85260	No Wait	Directions | Register
Thompson Peak ER 7400 E. Thomspon Peak Pkwy Scottsdale, AZ 85255	No Wait	Directions | Register

Information Last Updated: 1/21/2010 1:14:00 AM

Achieving Lean Flow

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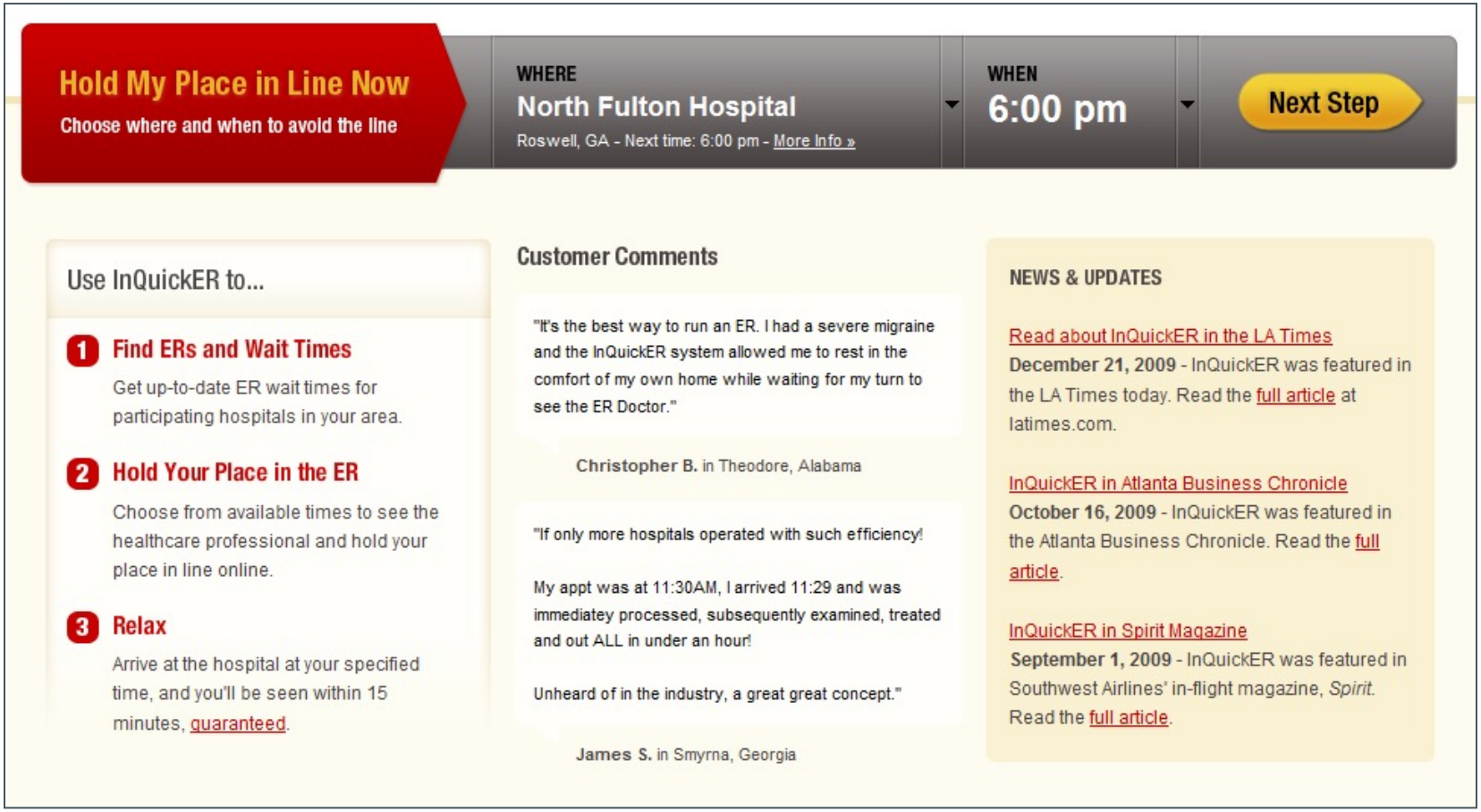
Affecting Variation in Arrivals…



Achieving Lean Flow

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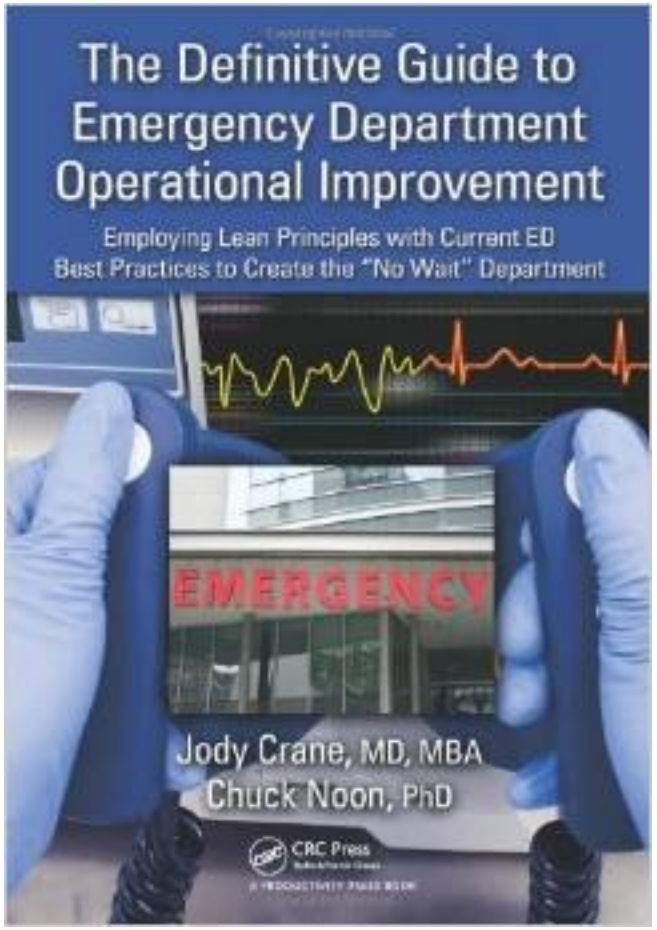
Lean Healthcare

- Focuses on creating patient value
- Eliminating waste
- Promoting flow
- Continuous improvement



Key Principles

- Focus on Processes that deliver Customer Value
  - Value-added – An activity in the process that moves the patient closer to wellness
  - Waste – Any other activity in the process

Waste – "TIM WOOD"

- Transportation
  - Unnecessary patient movement
- Inventory
  - Having more supplies than are necessary (gloves)
- Movement
  - Walking to various locations to get supplies
  - Covering beds in remote areas
- Waiting
  - Waiting to be seen
  - Waiting for biopsy or stress test results
- Over-processing
  - Multiple providers asking the same questions
  - Ordering too many tests
- Overproduction
  - Monitoring a patient that doesn't need to be monitored
  - Unnecessary ICU admission
- Defects
  - Rework of lab tests (hemolysis)
  - Repeat visits

Key Principles

- Focus on Processes that deliver Customer Value
- Eliminate waste
- Promote flow
  - Align capacity with demand
  - Establish clear signals and handoffs
  - Reduce variation
  - Eliminate Queues

Key Principles

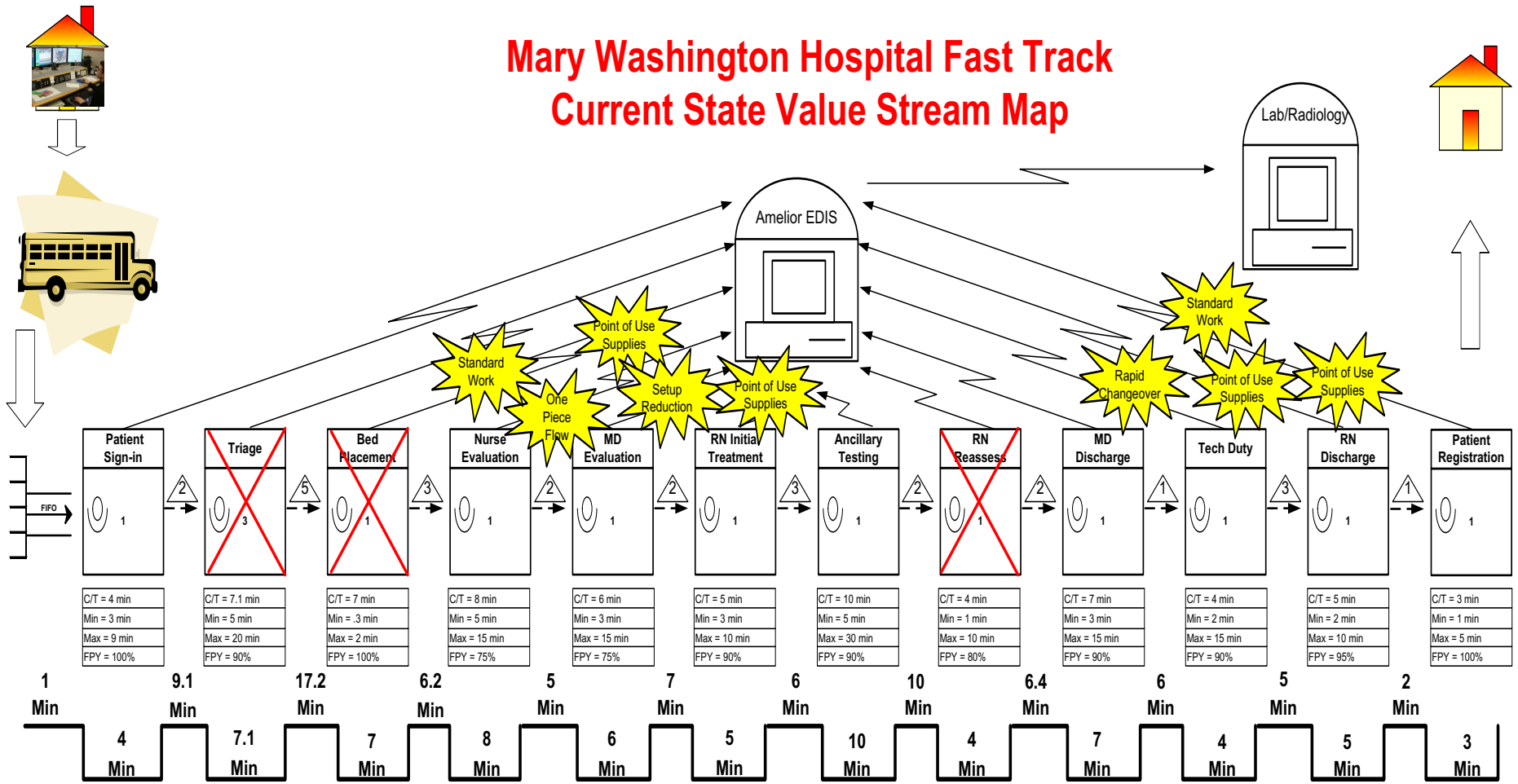
- Focus on Processes that deliver Customer Value
- Eliminate waste
- Promote flow
- Continuously improve the processes
  - Mastering change management
  - Creating a community of scientists
  - Willing to try, ok to fail, but always learning
  - PDCA, Rapid Cycle Testing (RCT) and Rapid Performance Improvement Events (RIEs)

Improvement Tools

- Process Mapping
- Standard Work, Demand/Capacity Management
- Workplace Organization
- Inventory Management (Pull systems), visual controls
- Setup/changeover reduction (Rapid Changeover)
- Mistake proofing, root cause analysis

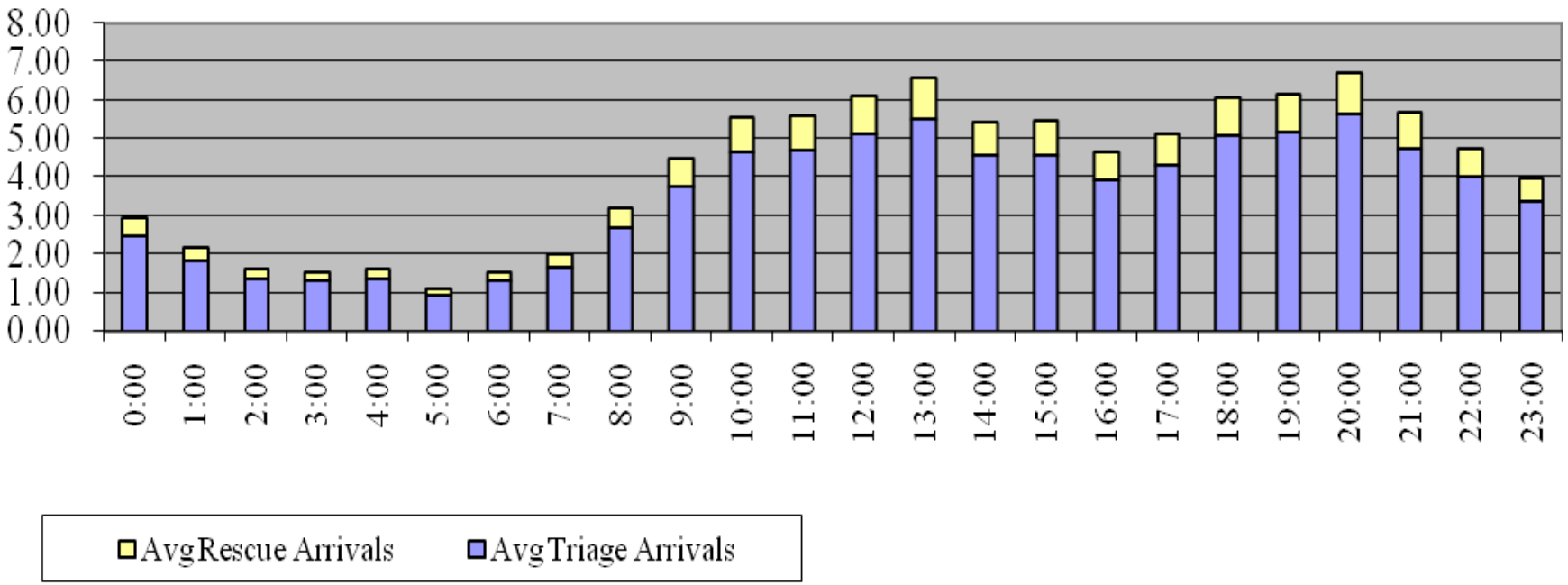
Process Mapping – “Low Tech”

Value, Waste, and Tools – System Improvements

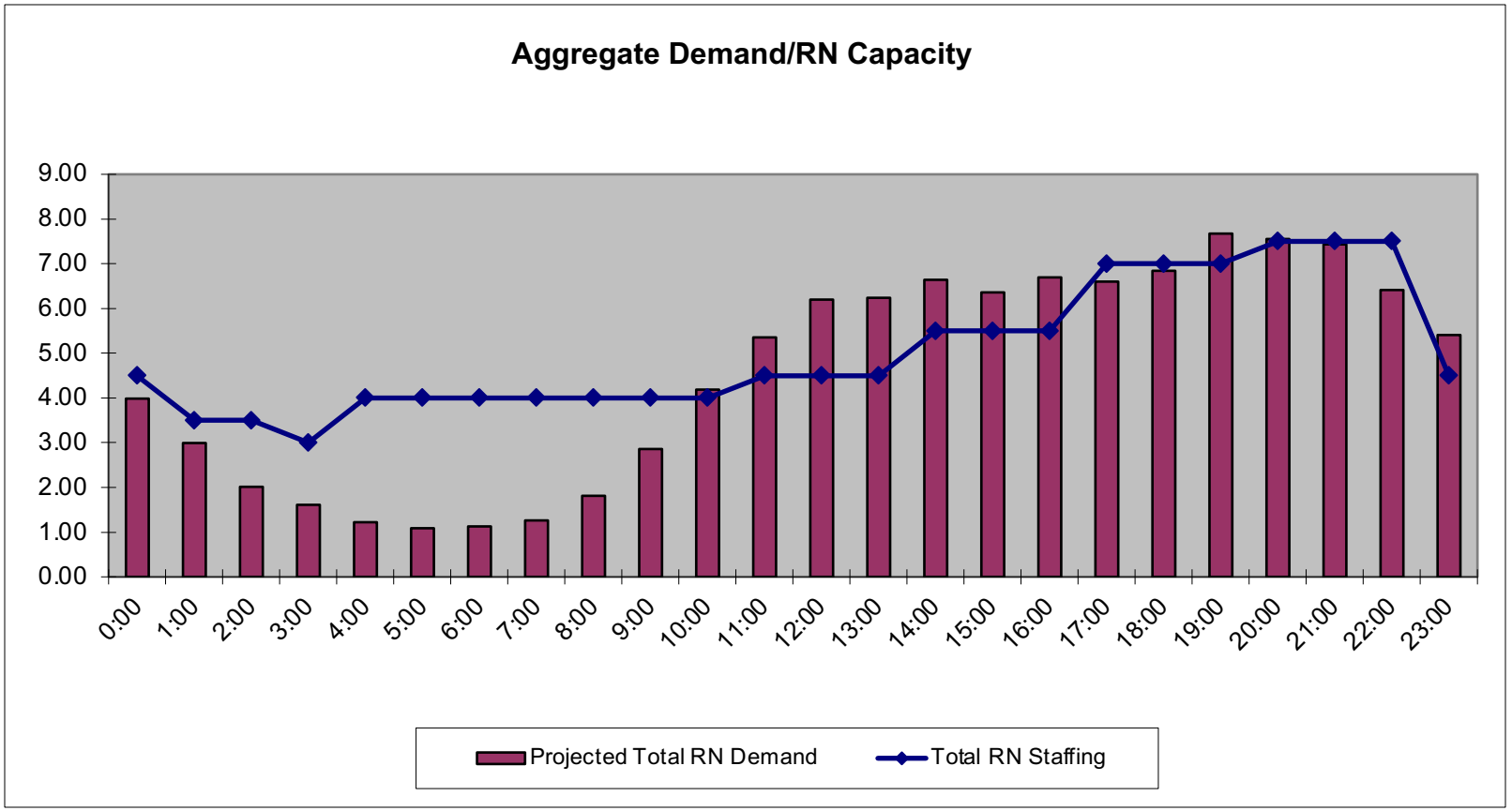


Total = 151 Minutes (2 hours and 31 minutes) Average LOS

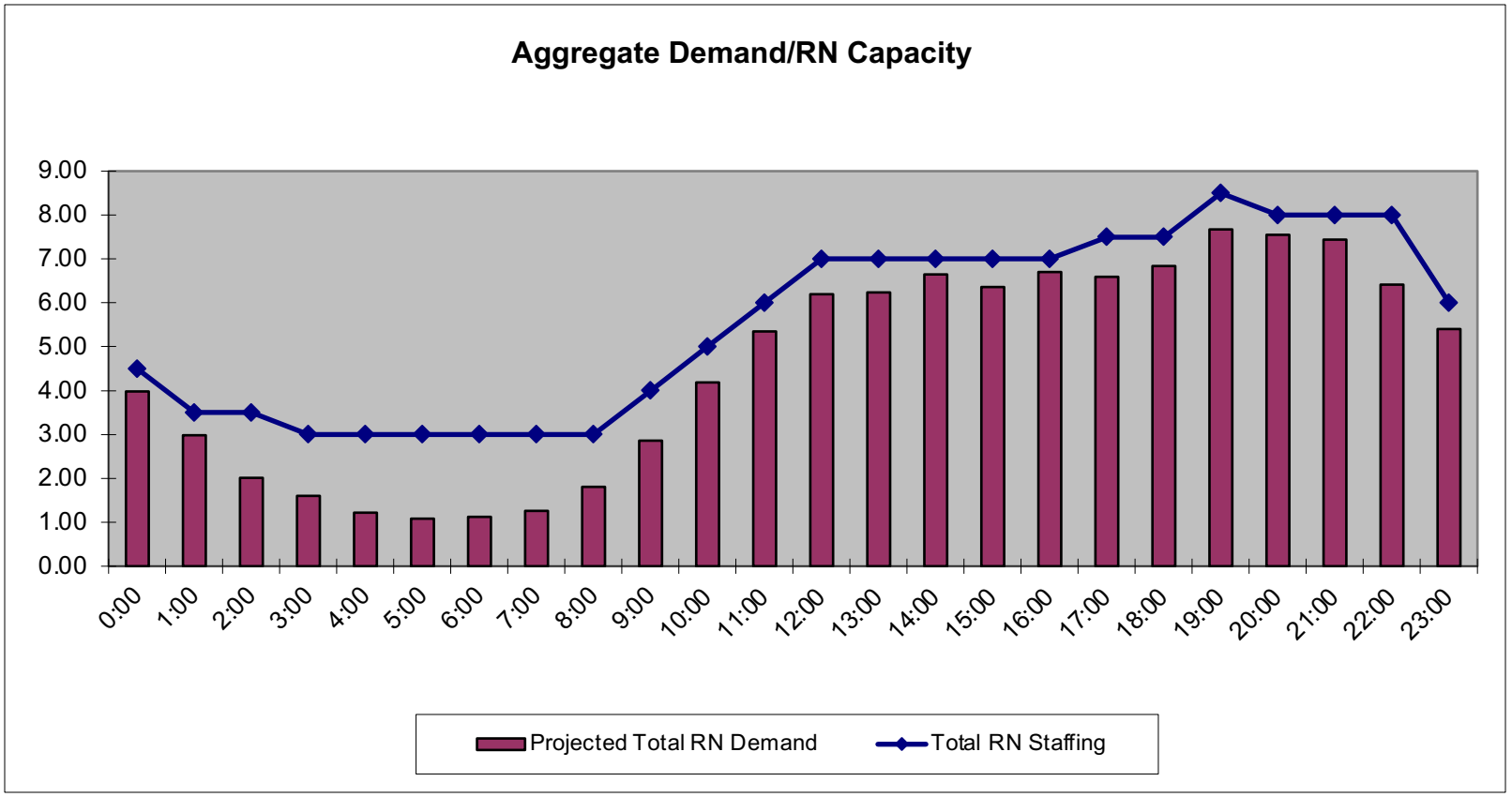
Hourly Demand



Stafford ED RN Demand/Capacity



Stafford ED RN Demand/Capacity



- Spaghetti Diagram of staff movement processing CT patients
- Total nursing and CT tech walking 4 hours per day
- Total annual cost $35,000

MWH Workplace Organization Project

Visual Management

Visual Nursing Server

Achieving Lean Flow

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- Add server capacity or change the *timing* of server capacity (align)

Academics

- The Theory of Constraints

Theory of Constraints – A Fast Track Example

Nurse

30 min/pt

Physician

3pts/hr

=

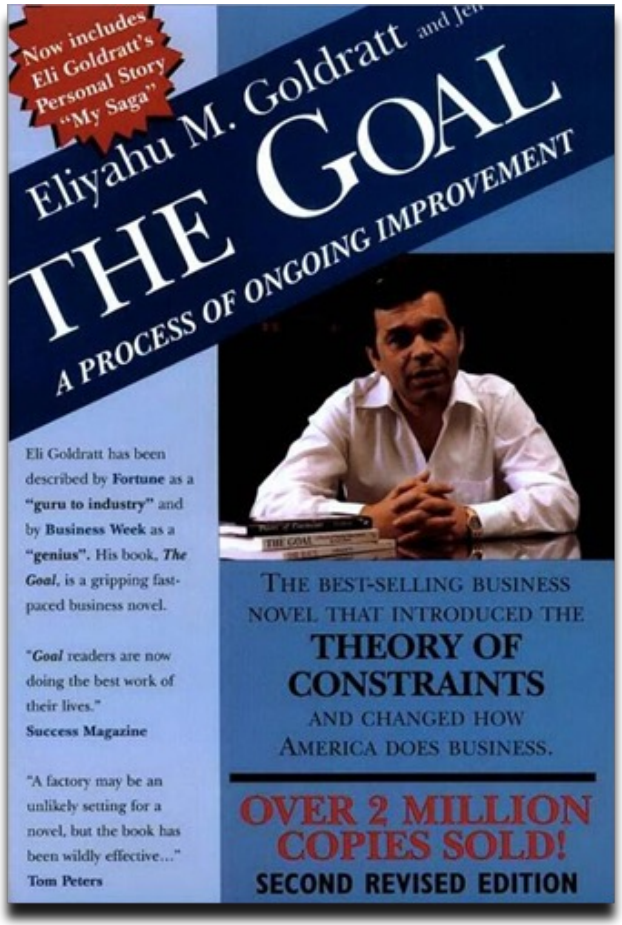
1) How many patients can my FT see per hour?

2) How can you improve this system if you cannot add resources?

TOC: The Theory of Constraints

- ***Bottleneck***- A resource that has the capacity equal to or less than the demand placed upon it

- ***Non-bottleneck***- A resource that has a capacity that is greater than the demand placed upon it



The Synergistic Power of RN and Provider Staffing Alignment

Chuck Noon, PhD
X32 Principal
TeamHealth Consultant

Todd Bethel, MD
SE Regional Clinical Analytics Director
TeamHealth

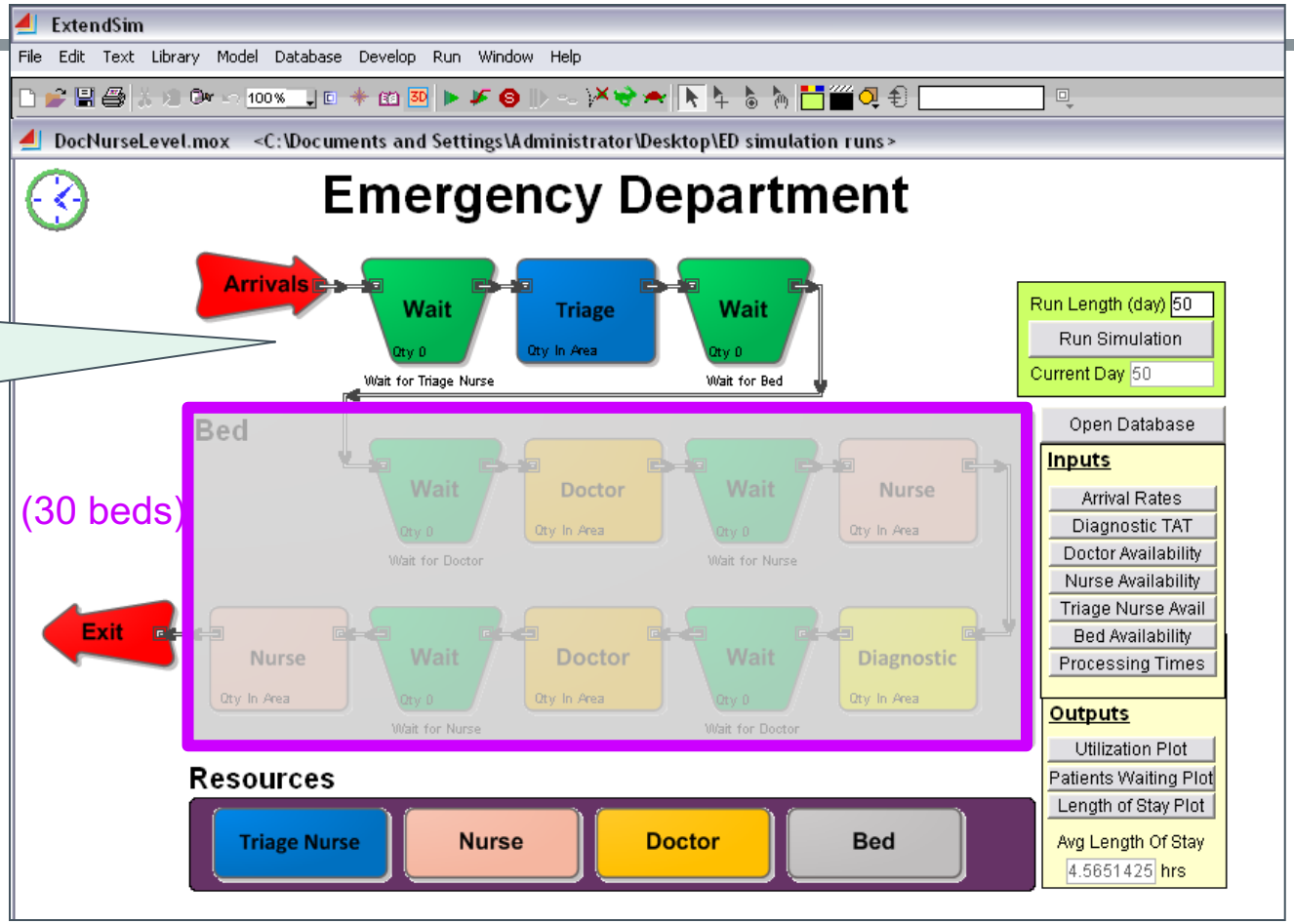
Theresa Tavernero, RN, MBA
Senior VP Performance Improvement
TeamHealth

TEAMHealth

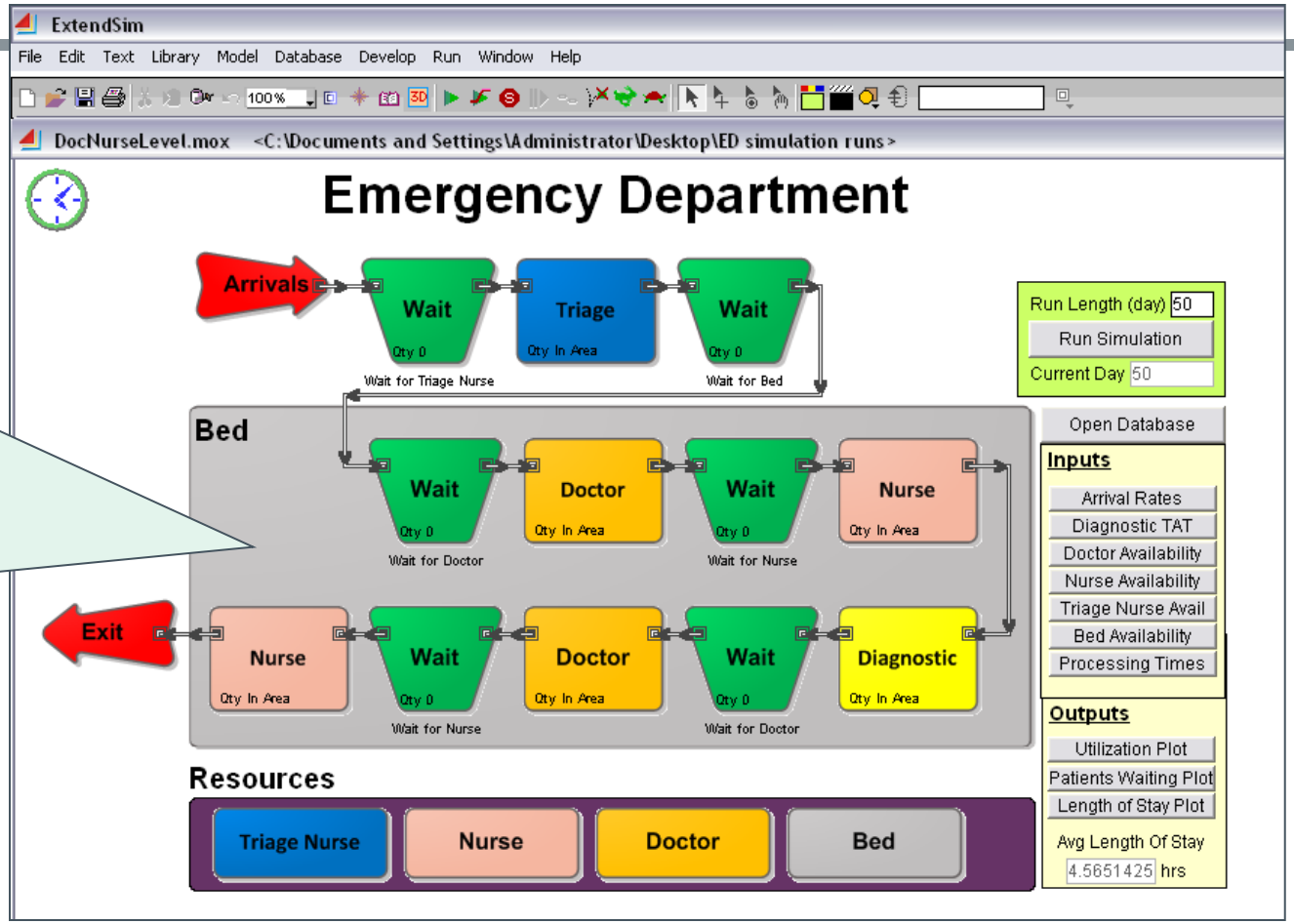
Simulating an ED with Multiple Resources

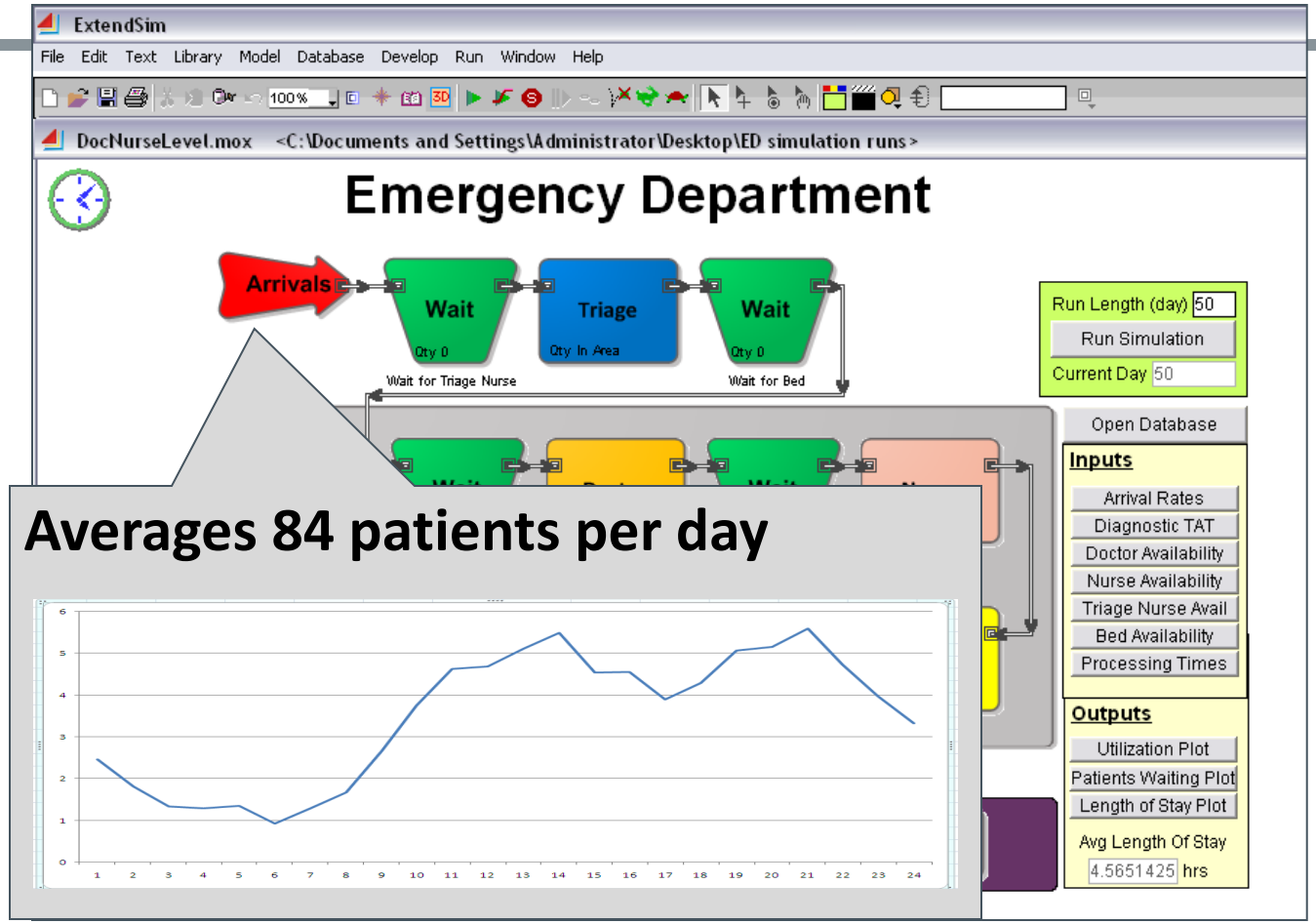
- We constructed a computer-based discrete event simulation to examine ED performance. Key attributes of the simulation include:
  - Hourly arrival rate averages that follow classic ED patterns, assumed real-world, hour-to-hour arrival variation
  - Key servers included MDs, RNs, Triage RN, and Beds
  - MDs, RNs, and Triage RN had average service times and appropriate measures of variation
  - A diagnostic activity with an average time and accompanying variation

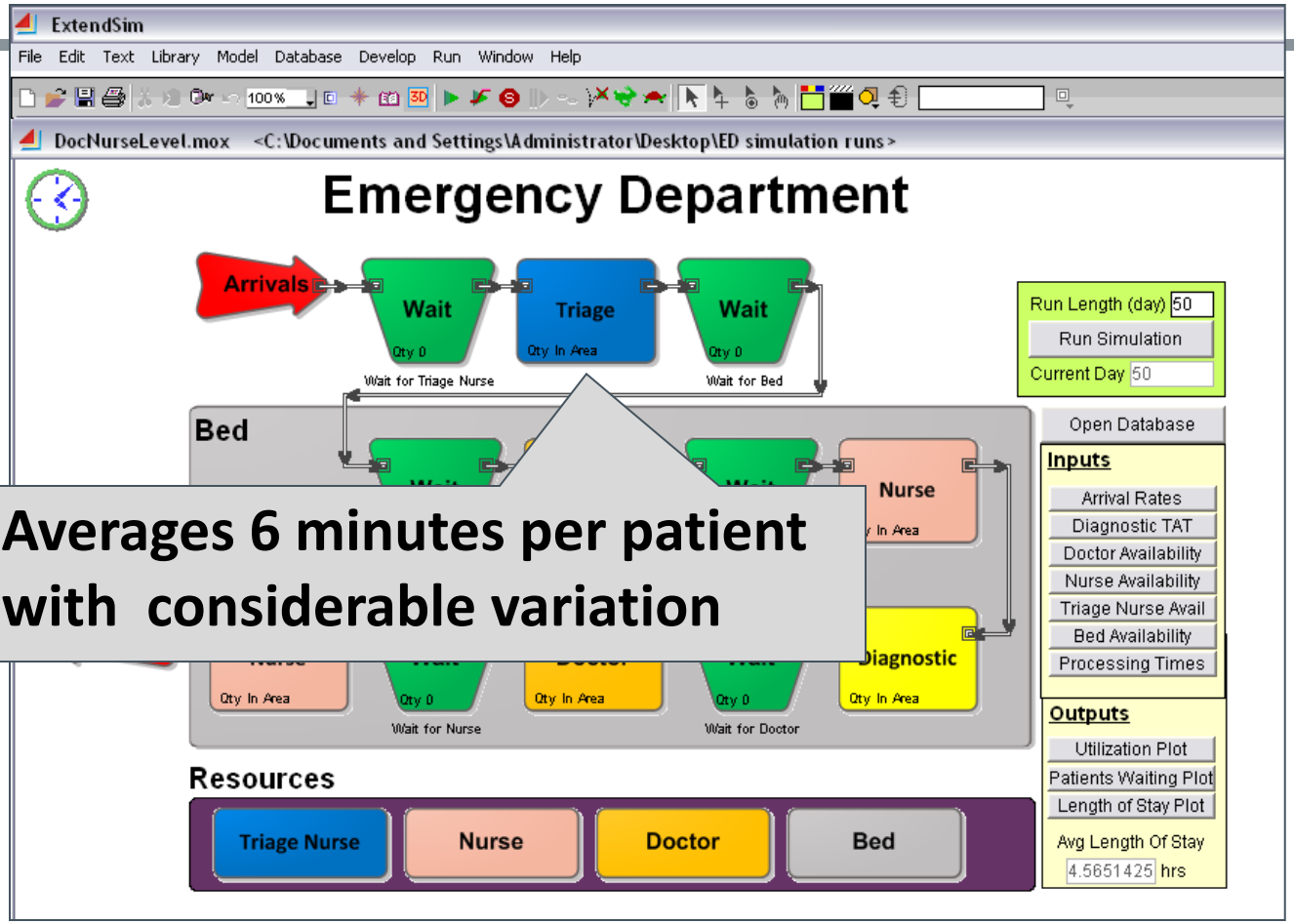
Patients arrive and have a triage encounter before being placed in a bed. The ED has 30 beds.



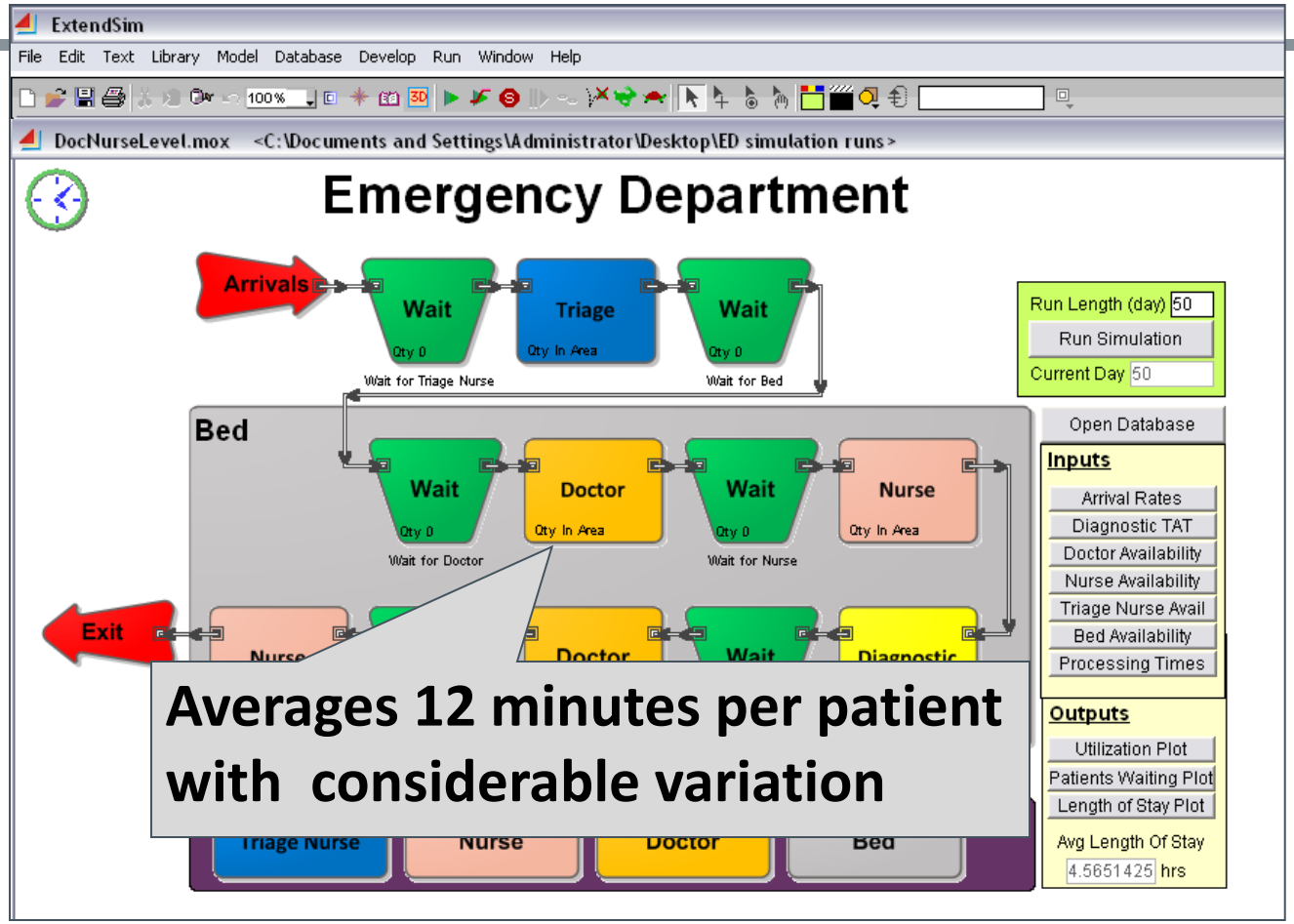
Once in a bed, the care activities occur in a sequence consisting of two separate MD encounters, two separate RN encounters, and a diagnostic encounter. Upon completion of all encounters, the patient exits the ED (i.e., no holds)




ExtendSim
File Edit Text Library Model Database Develop Run Window Help
DocNurseLevel.mox <C:\Documents and Settings\Administrator\Desktop\ED simulation runs>
Emergency Department
Arrivals
Wait
Qty 0
Triage
Qty In Area
Wait
Qty 0
Wait for Triage Nurse
Wait for Bed
Run Length (day) 50
Run Simulation
Current Day 50
Open Database
Inputs
Arrival Rates
Diagnostic TAT
Doctor Availability
Nurse Availability
Triage Nurse Avail
Bed Availability
Processing Times
Outputs
Utilization Plot
Patients Waiting Plot
Length of Stay Plot
Avg Length Of Stay
4.5651425 hrs
Averages 84 patients per day
0 1 2 3 4 5 6
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24



Averages 6 minutes per patient with considerable variation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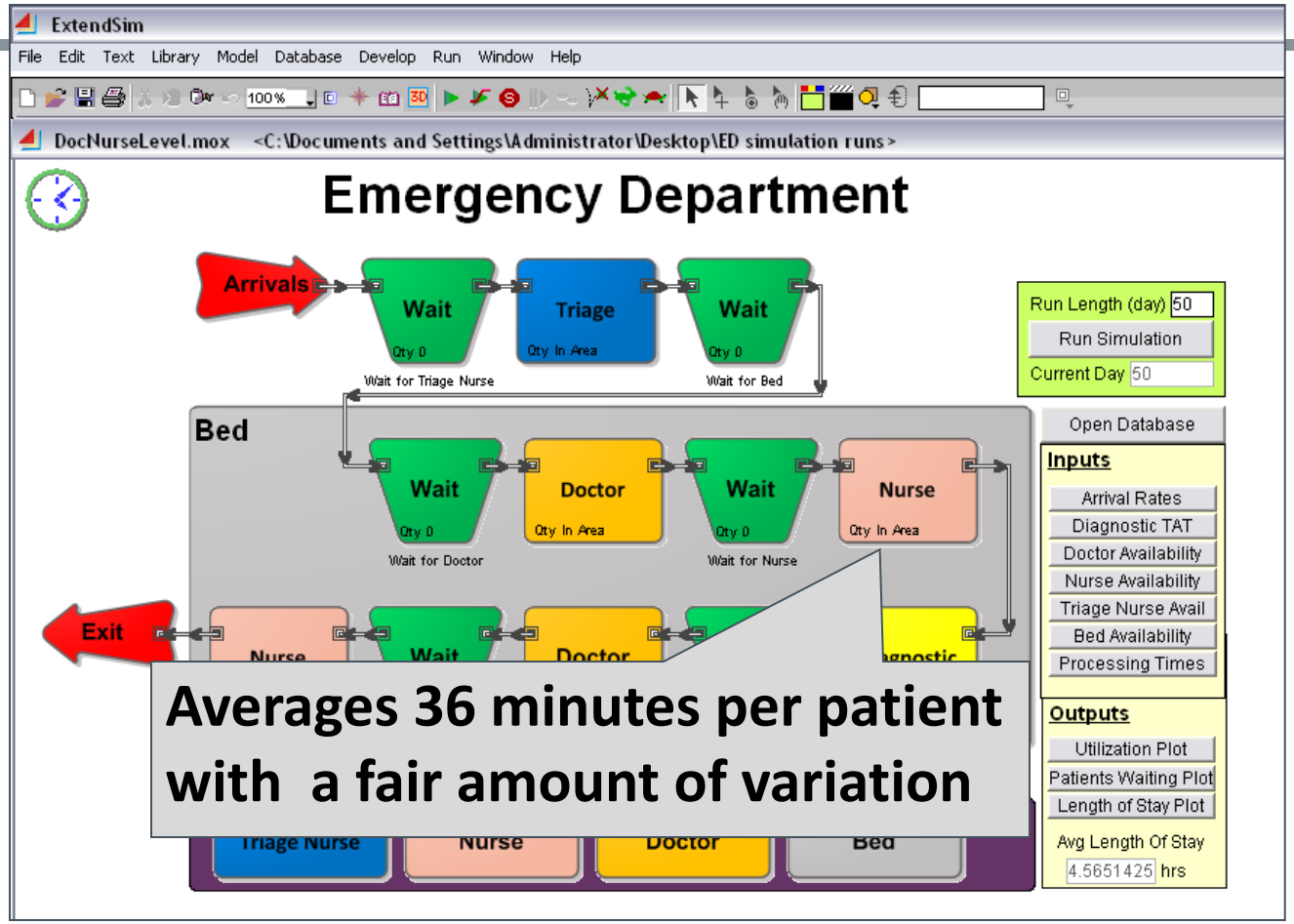
Emergency Department
Arrivals
Wait
Qty 0
Triage
Qty In Area
Wait
Qty 0
Wait for Triage Nurse
Wait for Bed
Bed
Wait
Qty 0
Doctor
Qty In Area
Wait
Qty 0
Nurse
Qty In Area
Wait for Doctor
Wait for Nurse
Exit
Triage Nurse
Nurse
Doctor
Bed
Run Length (day) 50
Run Simulation
Current Day 50
Open Database
Inputs
Arrival Rates
Diagnostic TAT
Doctor Availability
Nurse Availability
Triage Nurse Avail
Bed Availability
Processing Times
Outputs
Utilization Plot
Patients Waiting Plot
Length of Stay Plot
Avg Length Of Stay
4.5651425 hrs
Averages 12 minutes per patient with considerable variation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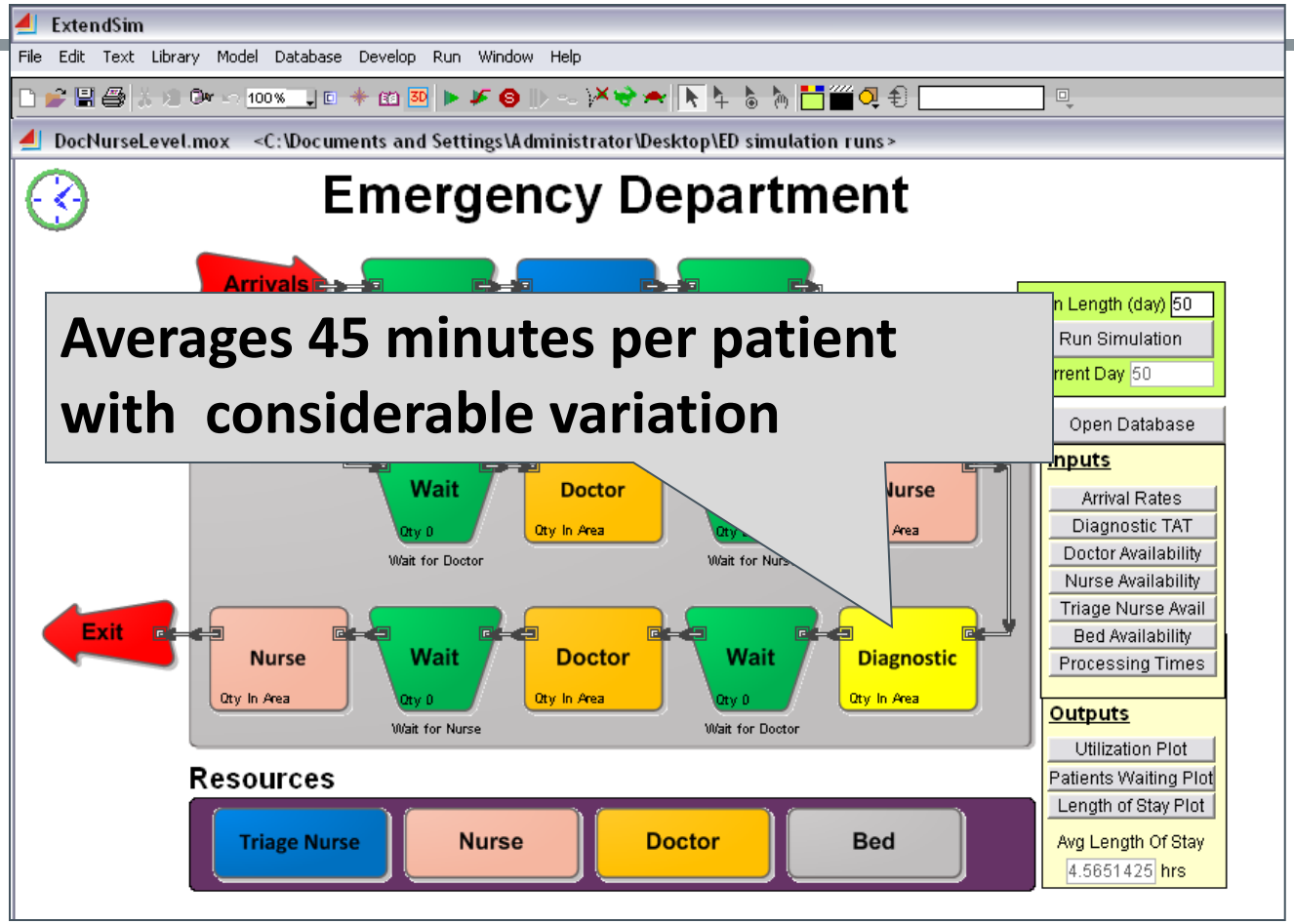
Emergency Department
Arrivals
Wait
Qty 0
Triage
Qty In Area
Wait
Qty 0
Wait for Triage Nurse
Wait for Bed
Bed
Wait
Qty 0
Doctor
Qty In Area
Wait
Qty 0
Nurse
Qty In Area
Wait for Doctor
Wait for Nurse
Exit
Nurse
Wait
Doctor
Triage Nurse
Nurse
Doctor
Bed
Run Length (day) 50
Run Simulation
Current Day 50
Open Database
Inputs
Arrival Rates
Diagnostic TAT
Doctor Availability
Nurse Availability
Triage Nurse Avail
Bed Availability
Processing Times
Outputs
Utilization Plot
Patients Waiting Plot
Length of Stay Plot
Avg Length Of Stay
4.5651425 hrs
Averages 36 minutes per patient with a fair amount of variation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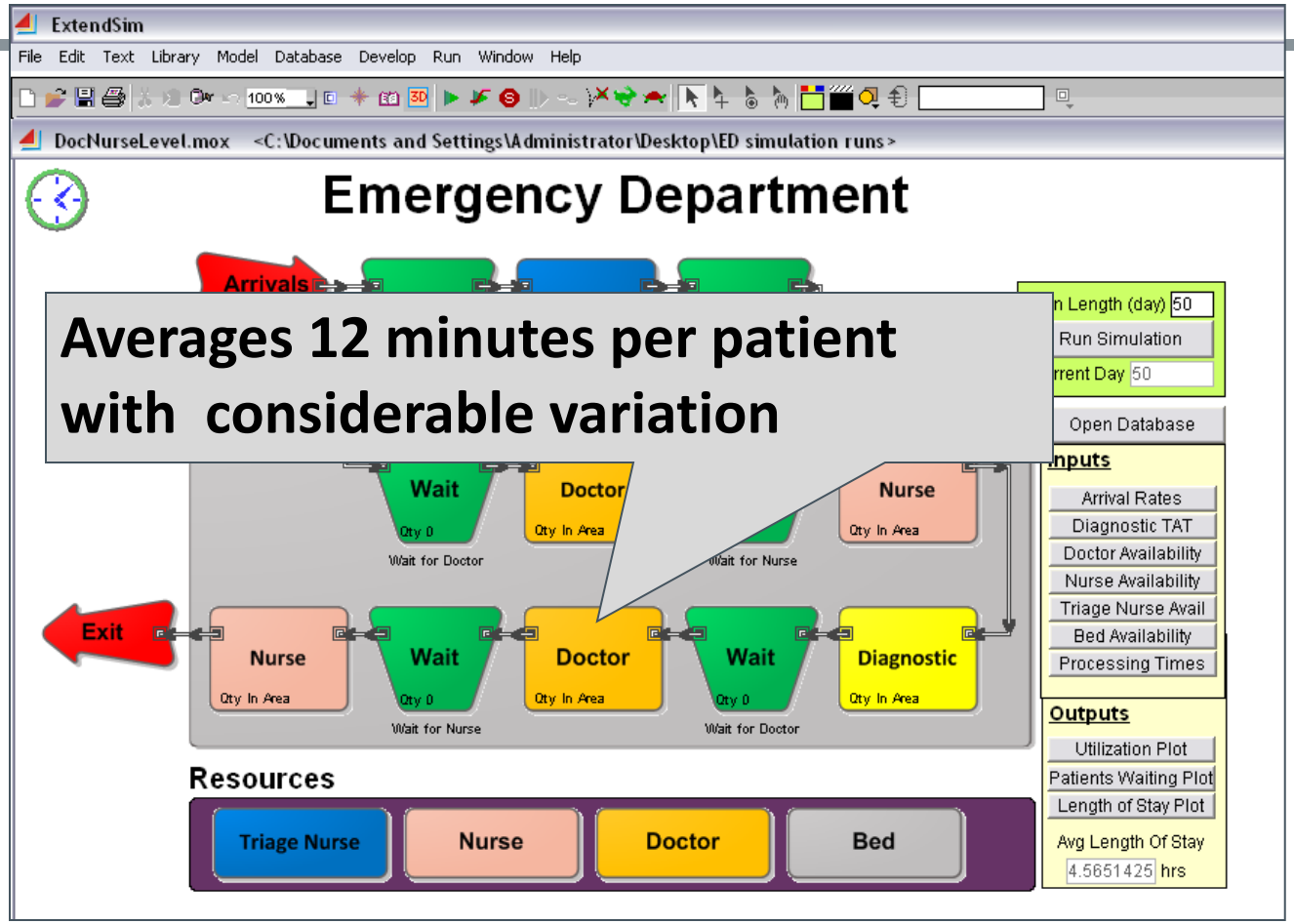
Emergency Department
Averages 45 minutes per patient with considerable variation
Arrivals
Exit
Nurse
Qty In Area
Wait
Qty 0
Wait for Nurse
Doctor
Qty In Area
Wait
Qty 0
Wait for Doctor
Diagnostic
Qty In Area
Resources
Triage Nurse
Nurse
Doctor
Bed
n Length (day) 50
Run Simulation
rrent Day 50
Open Database
nputs
Arrival Rates
Diagnostic TAT
Doctor Availability
Nurse Availability
Triage Nurse Avail
Bed Availability
Processing Times
Outputs
Utilization Plot
Patients Waiting Plot
Length of Stay Plot
Avg Length Of Stay
4.5651425 hrs


ExtendSim
File Edit Text Library Model Database Develop Run Window Help
DocNurseLevel.mox <C:\Documents and Settings\Administrator\Desktop\ED simulation runs>
Emergency Department
Averages 12 minutes per patient with considerable variation
Arrivals
Wait
Qty 0
Wait for Doctor
Doctor
Qty In Area
Nurse
Qty In Area
Wait for Nurse
Exit
Nurse
Qty In Area
Wait
Qty 0
Wait for Nurse
Doctor
Qty In Area
Wait
Qty 0
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Diagnostic
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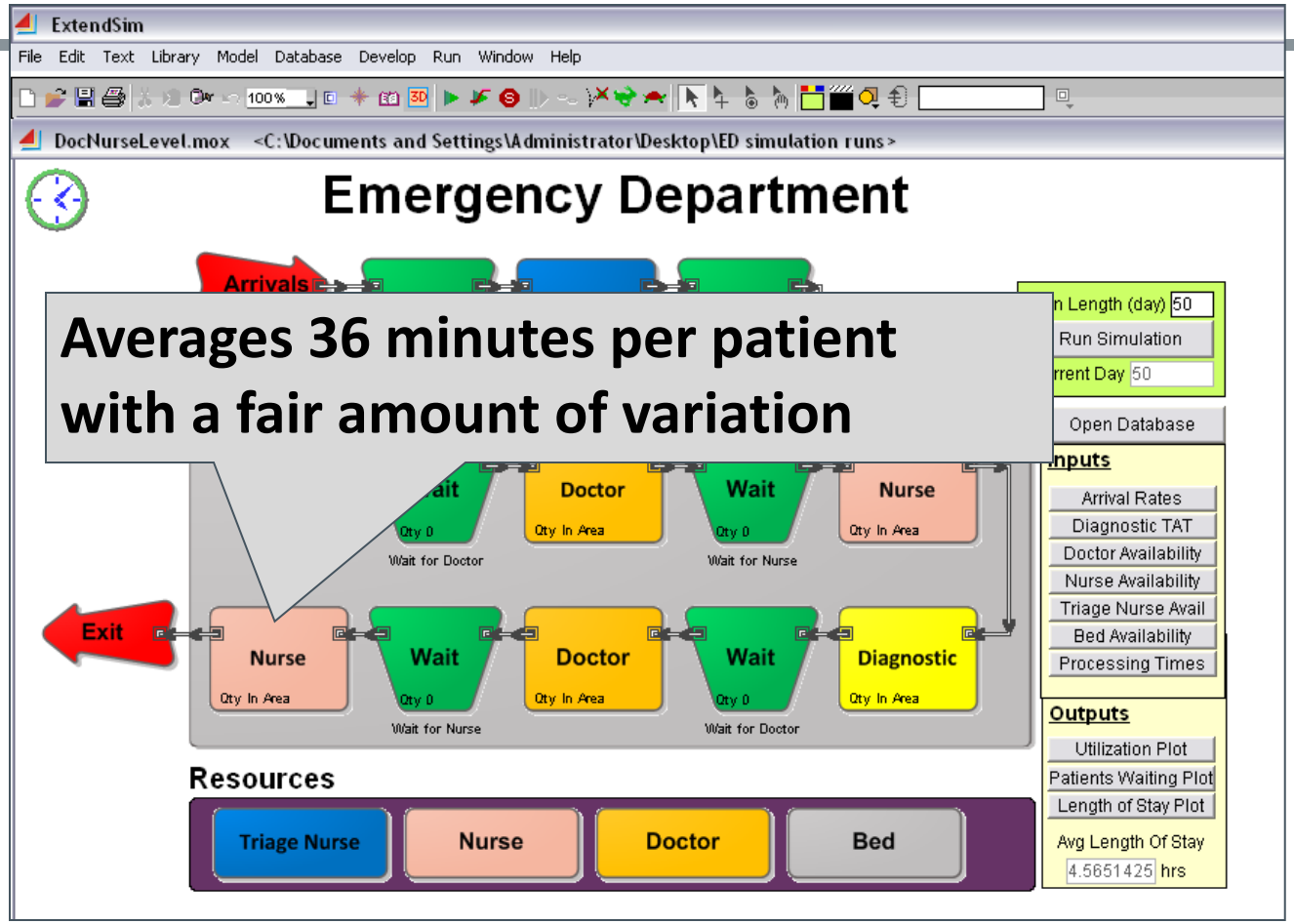
ExtendSim
File Edit Text Library Model Database Develop Run Window Help
DocNurseLevel.mox <C:\Documents and Settings\Administrator\Desktop\ED simulation runs>
Emergency Department
Averages 36 minutes per patient
with a fair amount of variation
Arrivals
Exit
Nurse
Qty In Area
Wait
Qty 0
Wait for Nurse
Doctor
Qty In Area
Wait for Doctor
Diagnostic
Qty In Area
Resources
Triage Nurse
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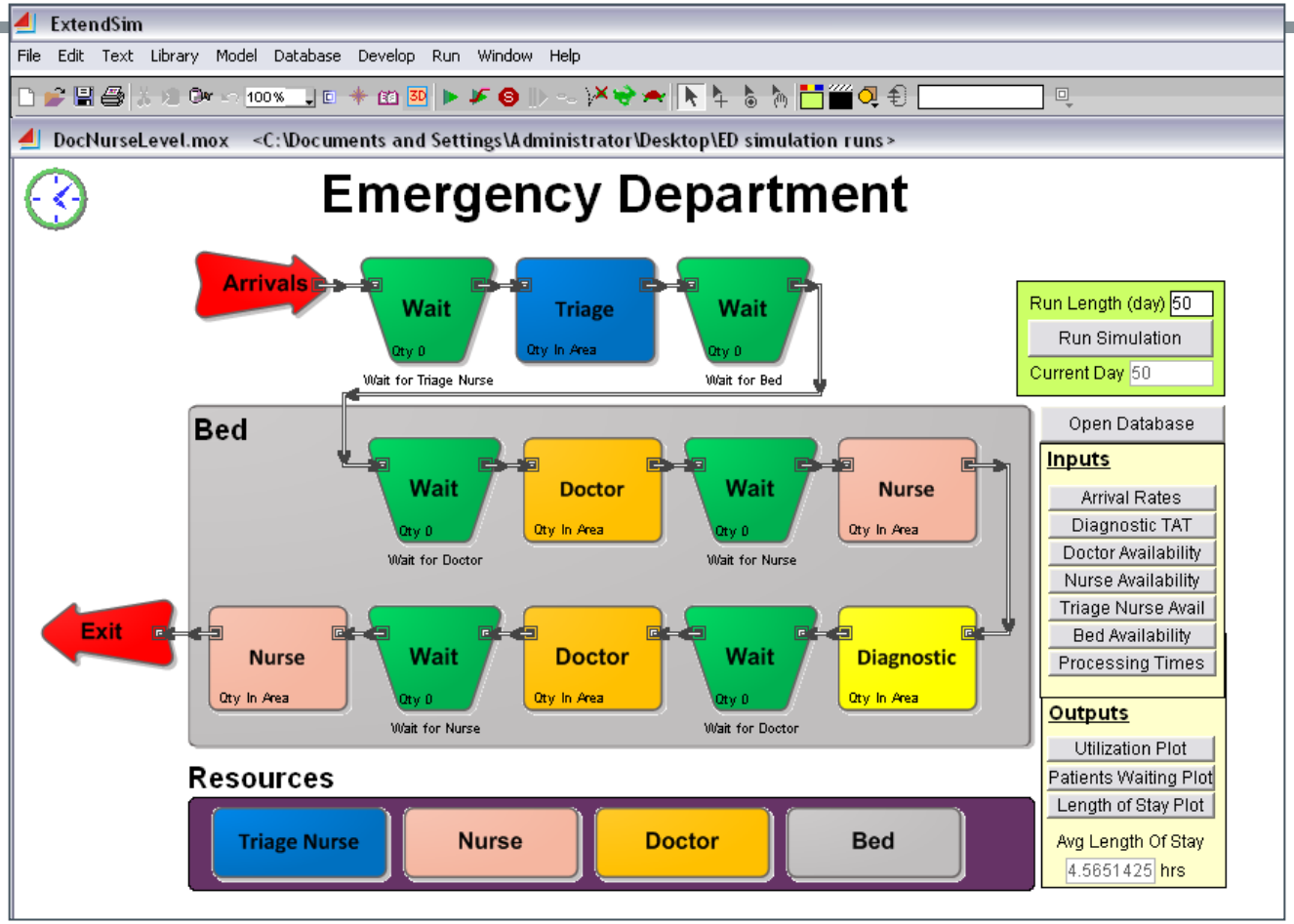
ExtendSim
File Edit Text Library Model Database Develop Run Window Help
100%
DocNurseLevel.mox <C:\Documents and Settings\Administrator\Desktop\ED simulation runs>
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Qty In Area
Wait
Qty 0
Wait for Triage Nurse
Wait for Bed
Bed
Wait
Qty 0
Doctor
Qty In Area
Wait
Qty 0
Nurse
Qty In Area
Wait for Doctor
Wait for Nurse
Exit
Nurse
Qty In Area
Wait
Qty 0
Doctor
Qty In Area
Wait
Qty 0
Diagnostic
Qty In Area
Wait for Nurse
Wait for Doctor
Resources
Triage Nurse
Nurse
Doctor
Bed
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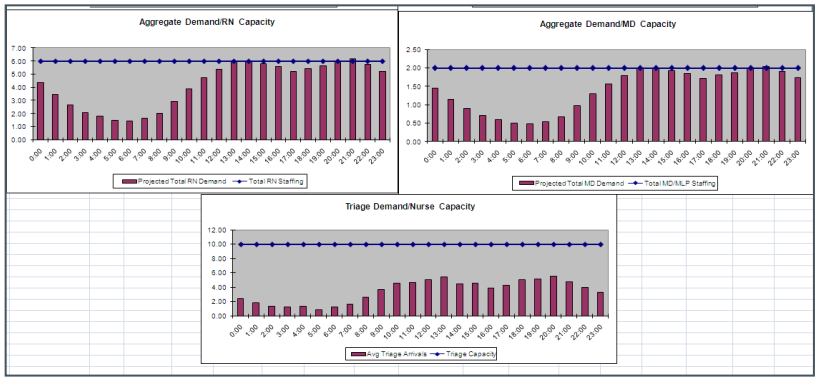
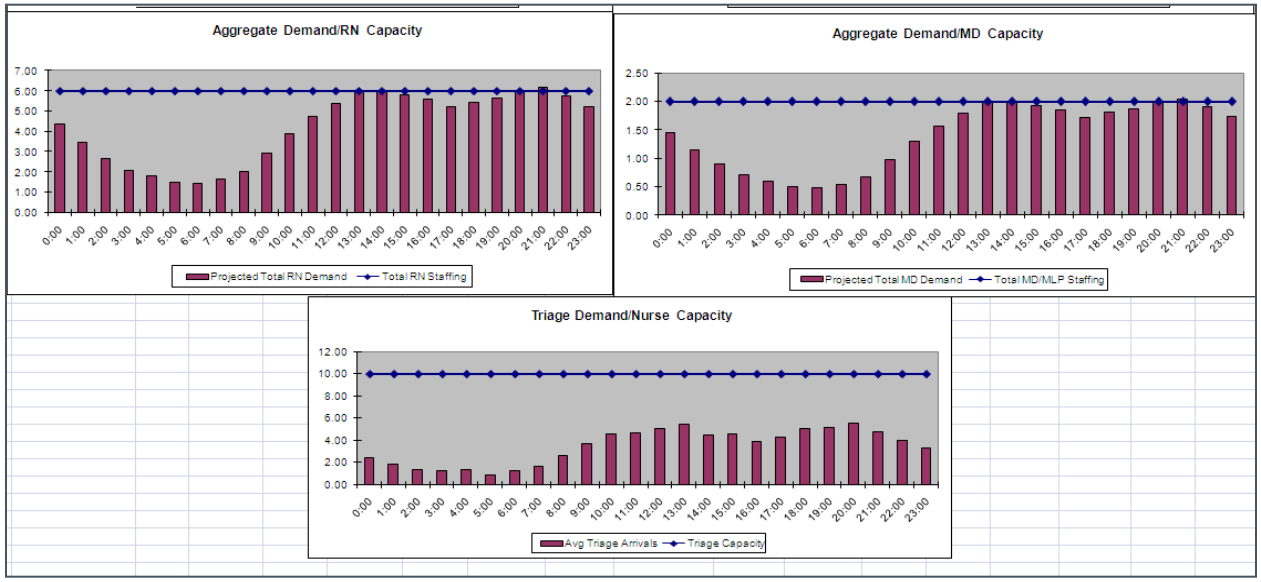
Avg Length Of Stay
4.5651425 hrs

Baseline Case Simulation

- **Total ”activity” per patient = 6+12+36+12+45+36 = 147 min**
  (Triage = 6 min, RN = 72 min, MD = 24 min, Diagnostic = 45 min)
- **Level Staffing as follows: 1 Triage RN, 6 RNs, 2 MDs**
- **84 patients/day**
- **Normal variation in arrival, provider times, ED processes**

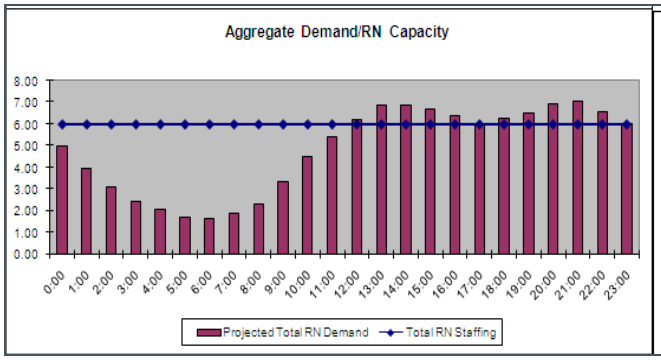


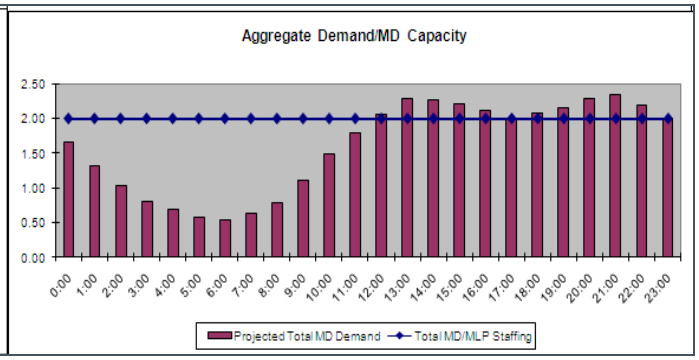
BASE CASE
MD & RN Level Staffing
LOS 3:40



BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing





What happens to patient length of stay (LOS) after a 15% increase in patient demand?

Stays the same

Increases by 8 minutes

Increases by 26 minutes

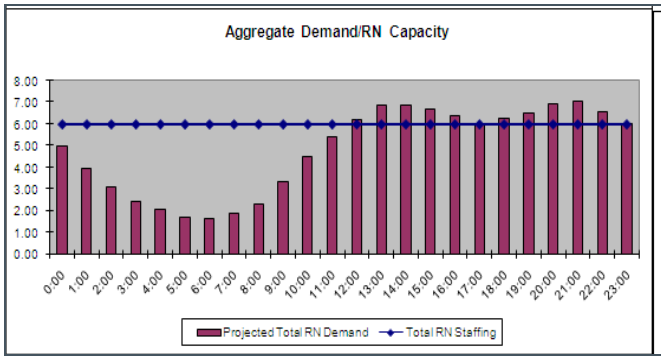
Increases by 37 minutes

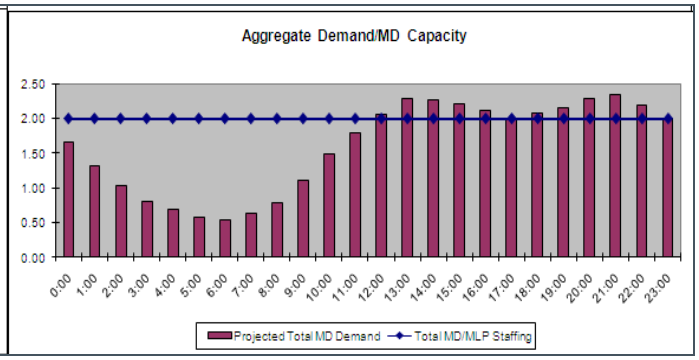
Increases by 54 minutes

Increases by greater than 54 minutes

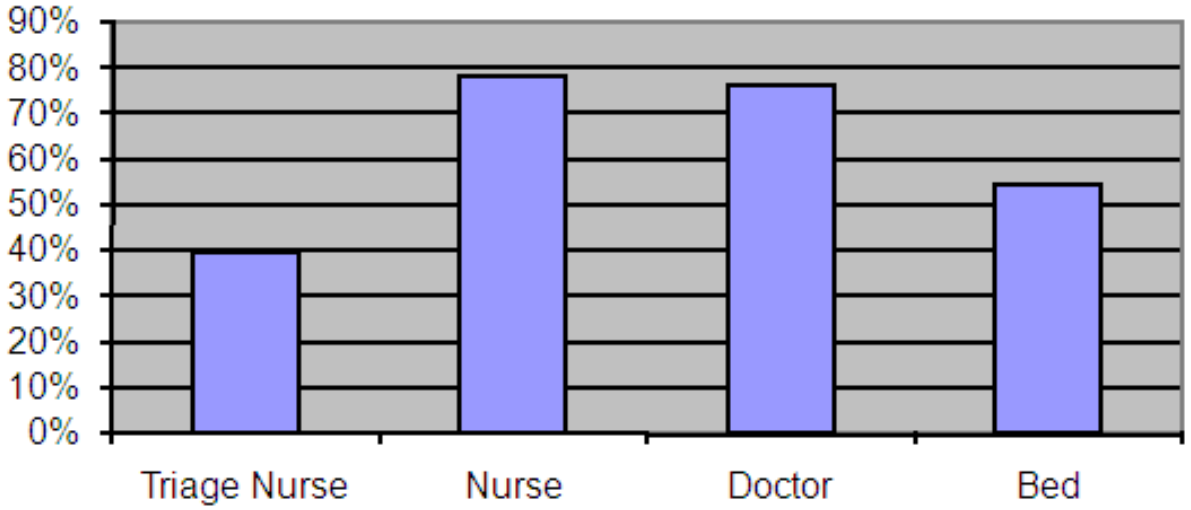
BASE CASE
MD & RN Level Staffing
LOS 3:40

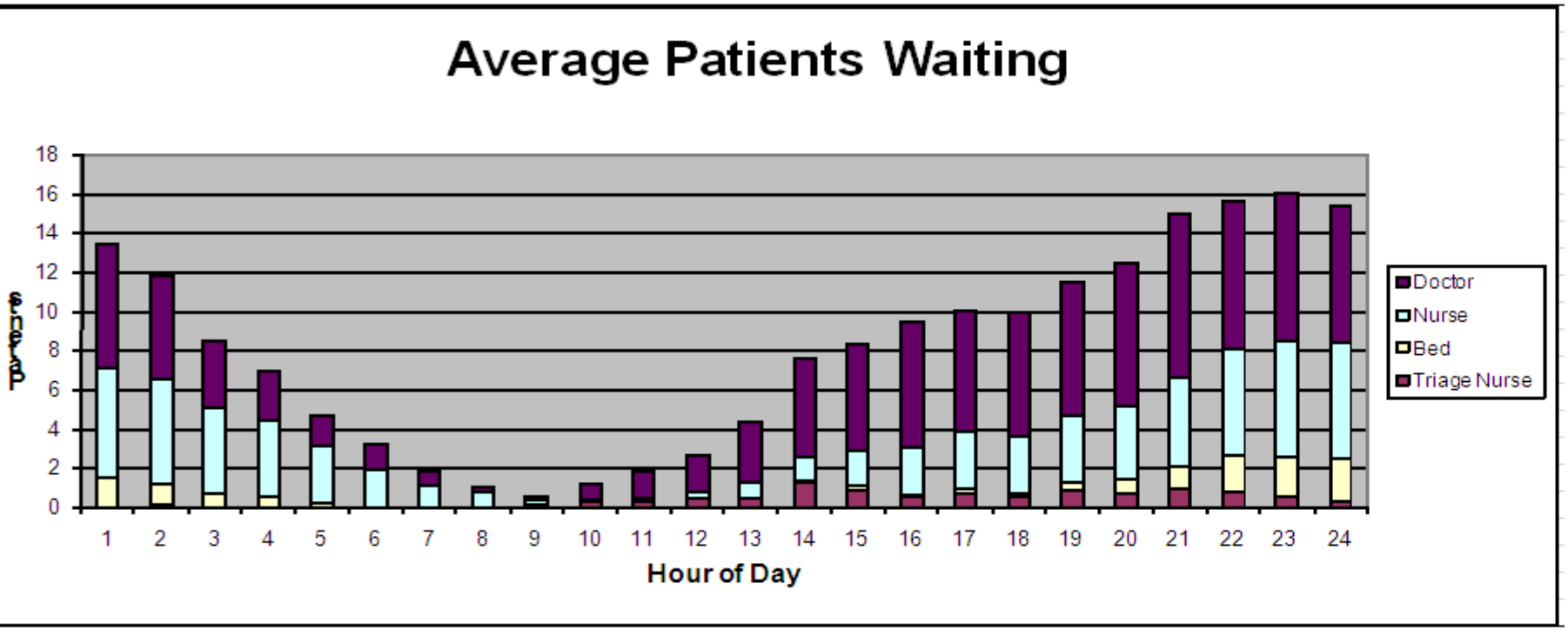
15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

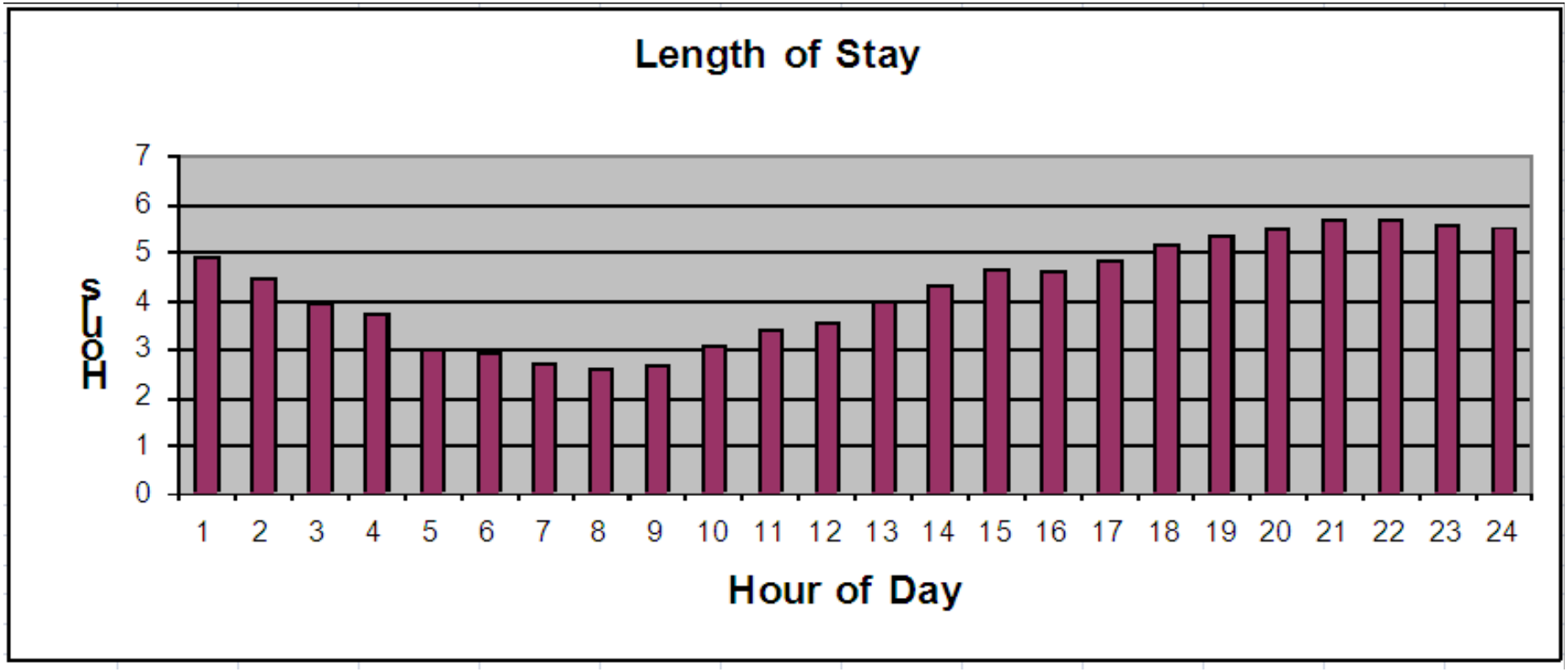




Resource Utilization



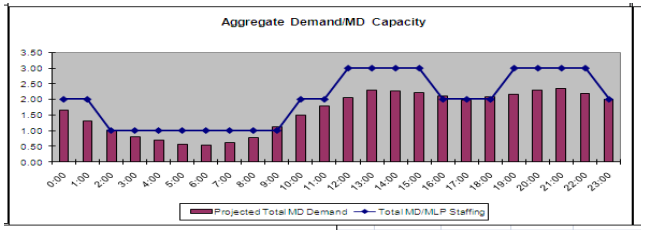

Average Patients Waiting
18
16
14
12
10
8
6
4
2
0
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day
Doctor
Nurse
Bed
Triage Nurse

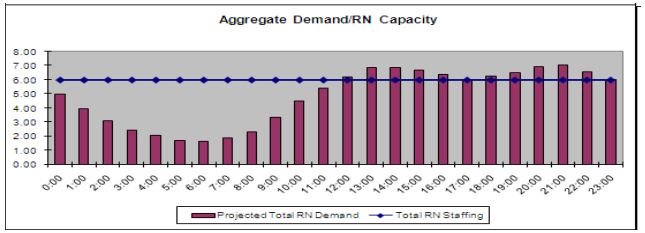

Length of Stay
LOS
0
1
2
3
4
5
6
7
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour of Day

BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

15% VOLUME INCREASE
MD Aligns & RN Level





What happens to patient length of stay (LOS) after physicians optimize?

Decreases less than 10 minutes

Decreases greater than 20 minutes

Stays the same

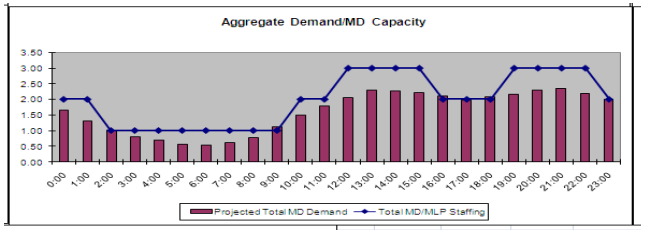
Increases less than 10 minutes

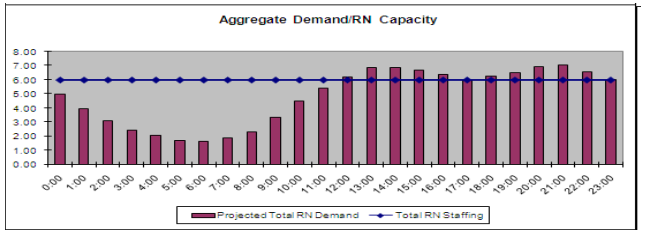
Increases greater than 20 minutes

BASE CASE
MD & RN Level Staffing
LOS 3:40

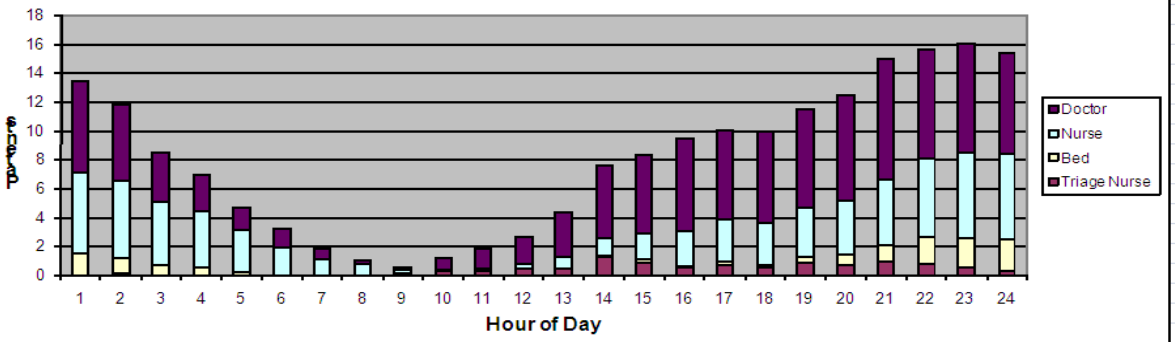
15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

15% VOLUME INCREASE
MD Aligns & RN Level
LOS 5:03

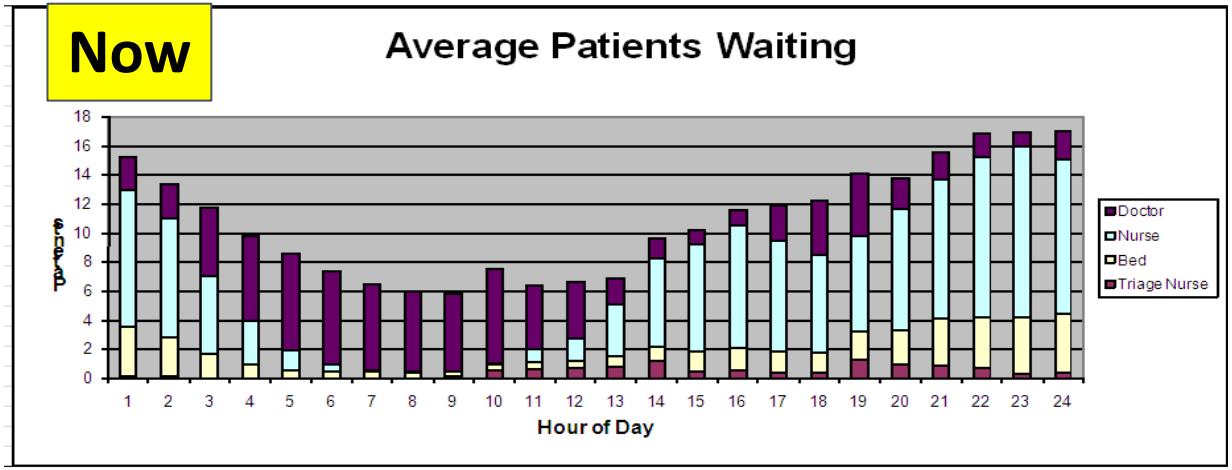




Previous



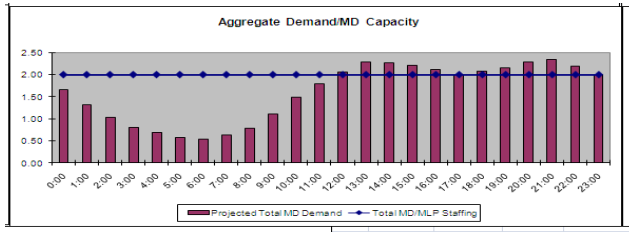
Now

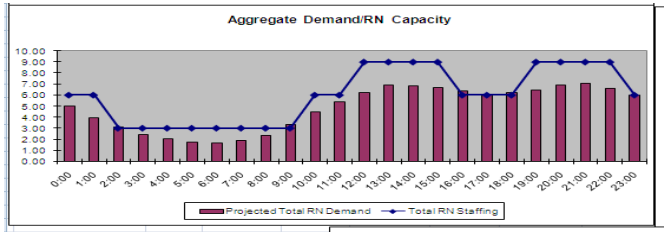


BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

15% VOLUME INCREASE
MD Level & RN Aligns

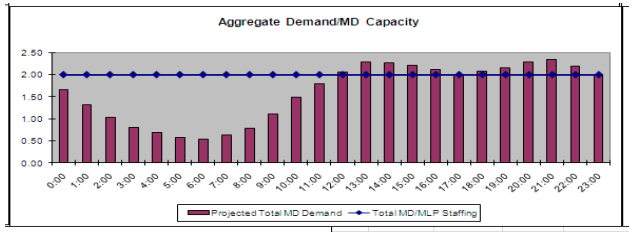


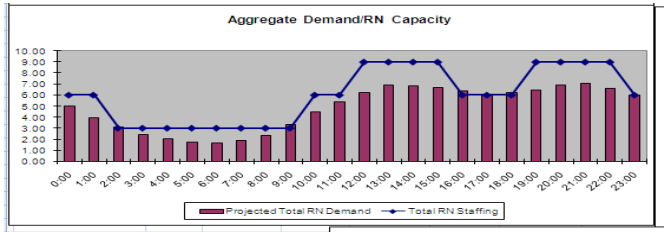


BASE CASE
MD & RN Level Staffing
LOS 3:40

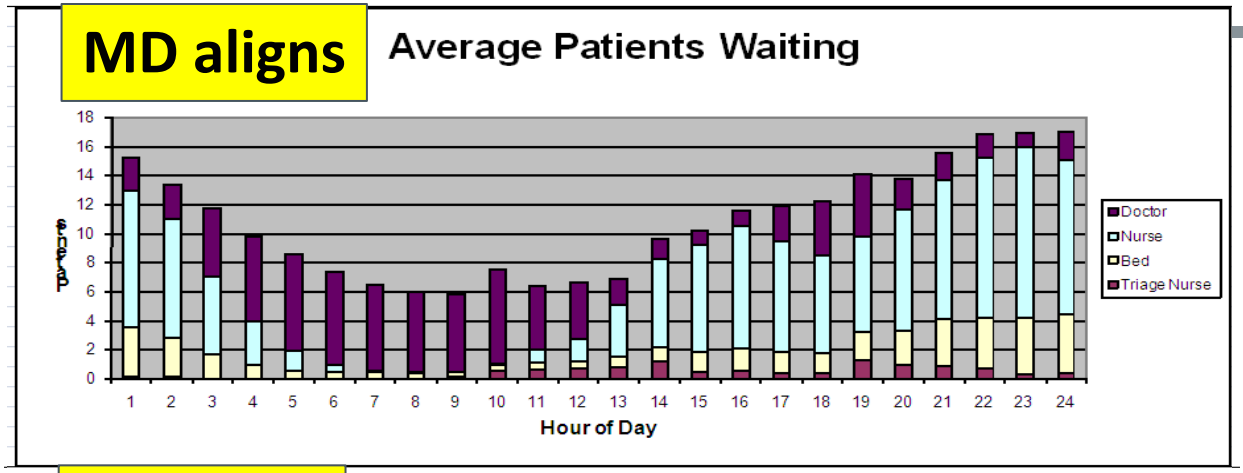
15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

15% VOLUME INCREASE
MD Level & RN Aligns
LOS 4:55

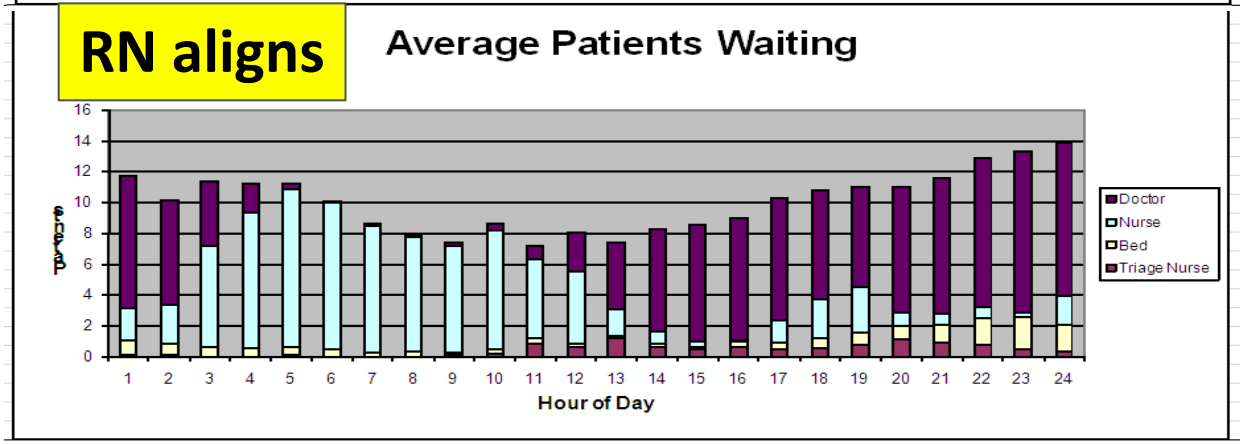




MD aligns



RN aligns



BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

15% VOLUME INCREASE
MD Aligns & RN Level
LOS 5:03

15% VOLUME INCREASE
MD Level & RN Aligns
LOS 4:55

BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

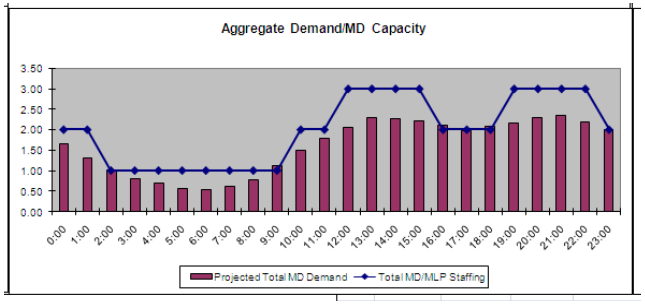
15% VOLUME INCREASE
MD Aligns & RN Level
LOS 5:03

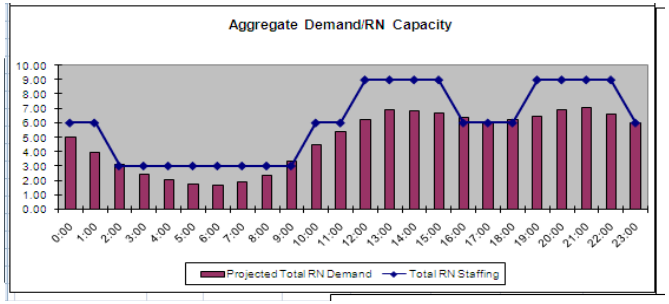
15% VOLUME INCREASE
MD Level & RN Aligns
LOS 4:55

15% VOLUME INCREASE
MD Aligns & RN Aligns

BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

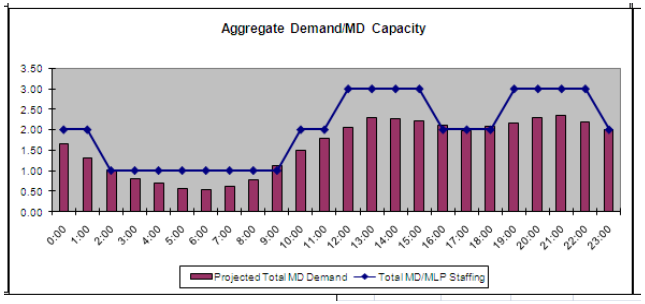


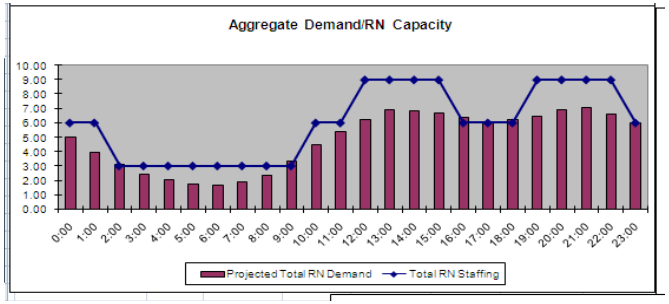


15% VOLUME INCREASE
MD Aligns & RN Aligns

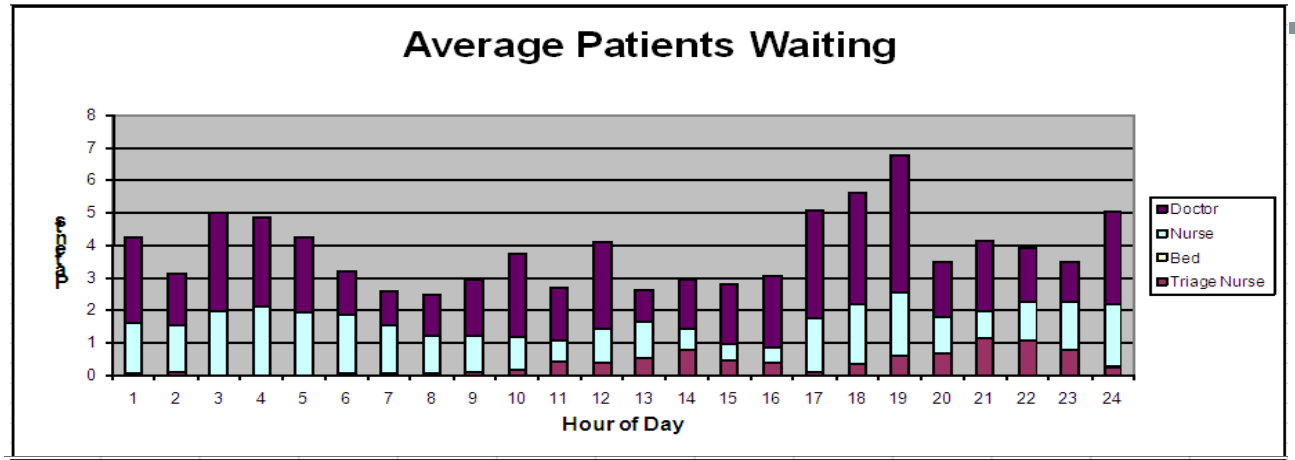
BASE CASE
MD & RN Level Staffing
LOS 3:40

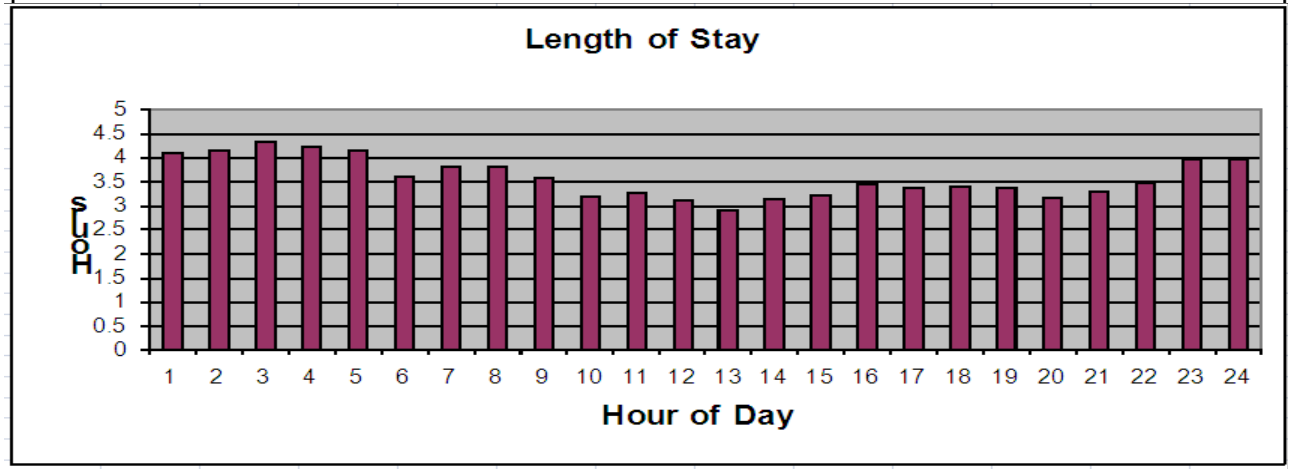
15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34





15% VOLUME INCREASE
MD Aligns & RN Aligns
LOS 3:27


Average Patients Waiting
Doctor
Nurse
Bed
Triage Nurse
Hour of Day

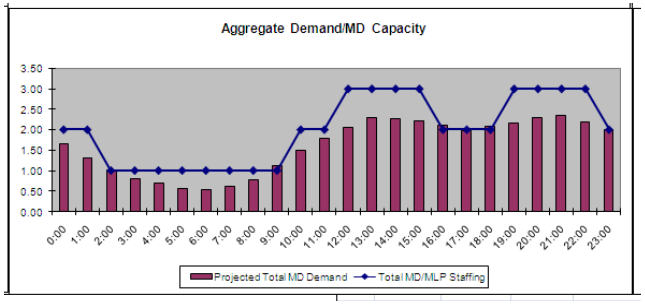

Length of Stay
Hour of Day

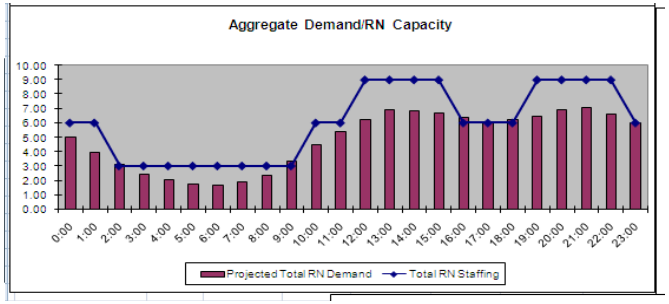
Simulation Insights

- Patient flow is optimized only if all primary resources are properly aligned throughout the day. Improving the alignment of only one resource may not generate improvement and may even make things worse.
- Let’s now take a look at staffing level sensitivity…

BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

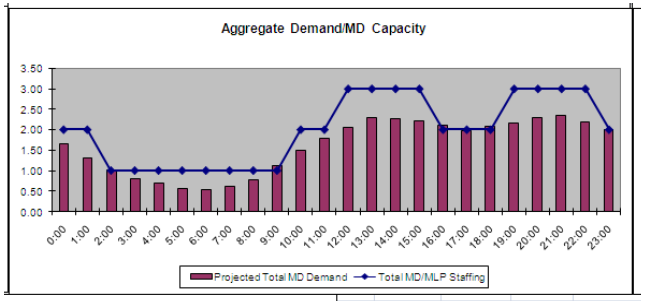


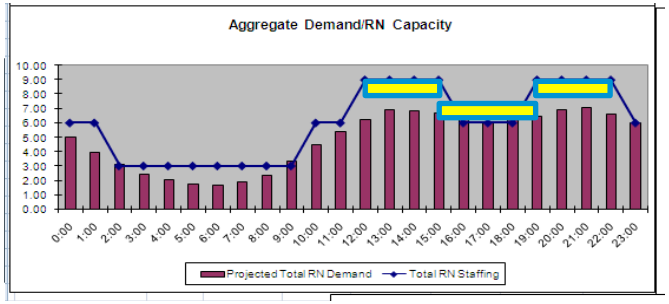


15% VOLUME INCREASE
MD Aligns & RN Aligns
LOS 3:27

BASE CASE
MD & RN Level Staffing
LOS 3:40

15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34



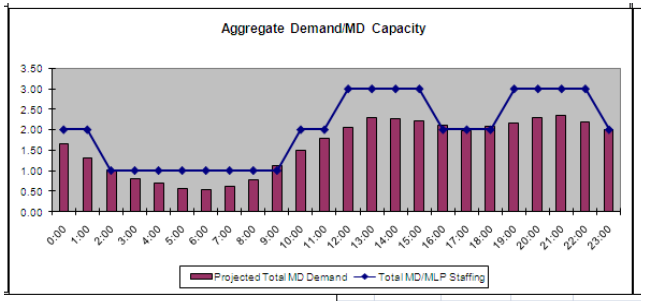


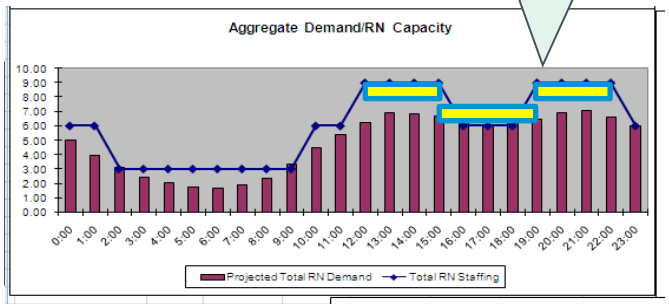
15% VOLUME INCREASE
MD Aligns & RN Aligns
LOS 3:27

BASE CASE
MD & RN Level Staffing
LOS 3:40

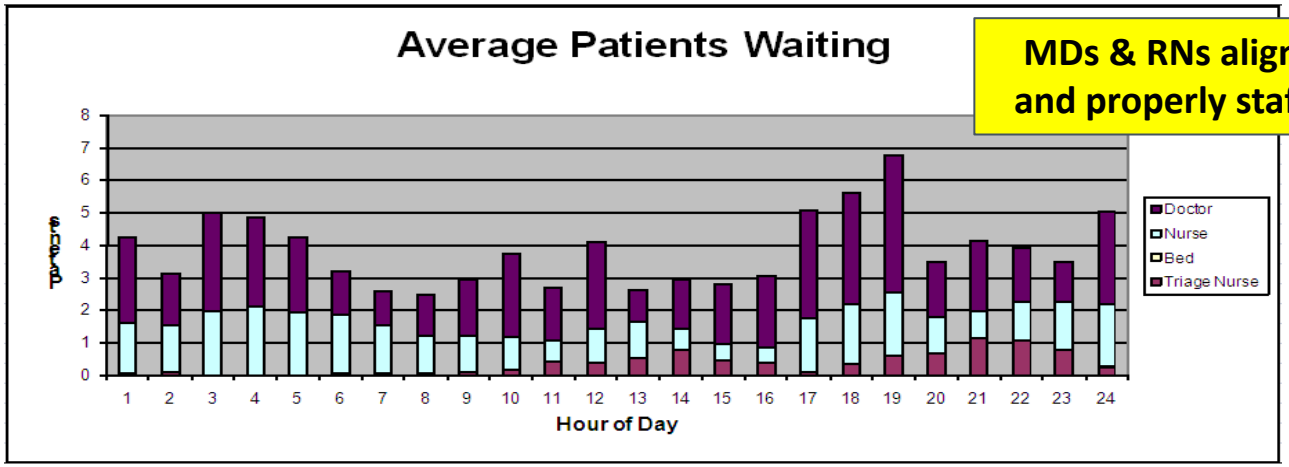
15% VOLUME INCREASE
MD & RN Level Staffing
LOS 4:34

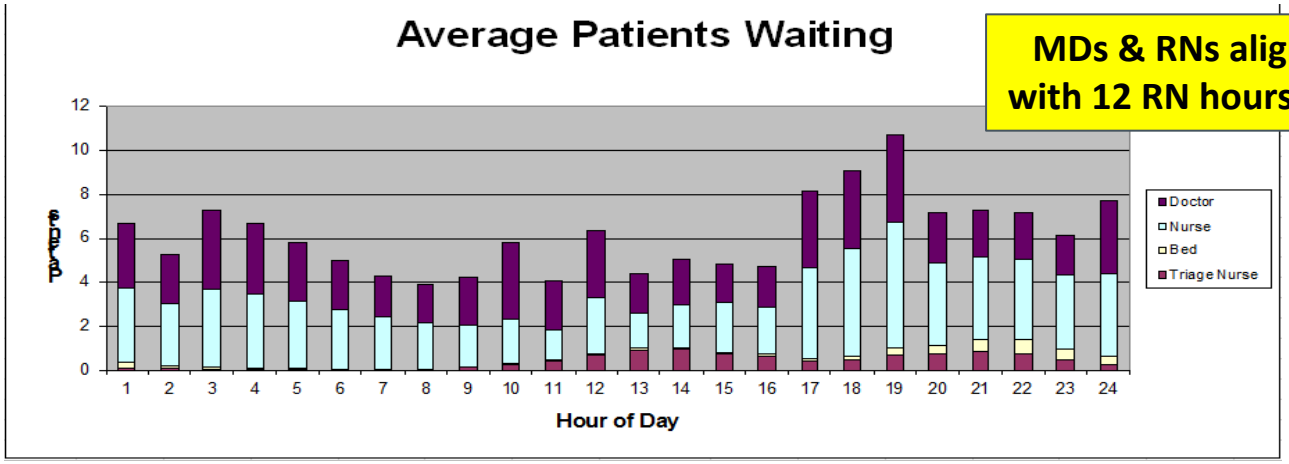
We lowered the peak periods staffing by 1 RN shift (12 hours) and re-ran the simulation.





15% VOLUME INCREASE
MD Aligns & RN Aligns
LOS ~~3:27~~ 4:01


Average Patients Waiting
MDs & RNs aligned and properly staffed
Hour of Day
Doctor
Nurse
Bed
Triage Nurse


Average Patients Waiting
MDs & RNs aligned, but with 12 RN hours removed
Hour of Day
Doctor
Nurse
Bed
Triage Nurse

Simulation Insights

- Patient flow is optimized only if all primary resources are properly aligned throughout the day.

Simulation Insights

- Patient flow is optimized only if all primary resources are properly aligned throughout the day.
- Even a relatively small amount of understaffing of *any* key set of servers will hurt patient flow, extend in-bed LOS, and ultimately cause a decrease in the productivity of ER staff.

Summary

- In order to optimize staffing in the emergency department, you must understand the underlying academics.
- Queuing theory explains the non-linear relationships between variation, utilization, and waiting.
- Both queuing theory and the Lean concept of standard work are used in creating the perfect alignment of resources.
- The theory of constraints ensures that, if you do have flow issues, you are focused on the right variable that will improve the system.