PREDICTIVE MODELING OF EMERGENCY DEPARTMENT OPERATIONS:

EFFECT OF PATIENTS' LENGTH OF STAY ON ED DIVERSION

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Froedtert Hospital, Milwaukee WI

- Primary teaching Hospital for MCW
- Tertiary Referral Center
- Level 1 Trauma Center for SE Wisconsin
- 433 staffed acute care beds
- 23,617 admissions/ 47,176 ED Visits
- 454,780 Outpatient Clinic Visits
- Surgeries - Inpt: 9,034/ Outpt: 5,711

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PROBLEM STATEMENT:

• Froedtert Hospital ED ambulance diversion has become unacceptably high due to no ED beds_(average ~21% of time in 2007)

•There are two big groups of patients:

(i) admitted to the hospital, and
(ii) treated, stabilized and discharged home

• Among factors that affect ED diversion patients' Length of Stay (LOS) in ED is one of most significant one.

The Goal of this work was:

• develop a methodology that could quantitatively analyze and predict an impact of patients' LOS on ED diversion (both for admitted and discharged home patients' groups).

• identify the maximum LOS limit that will result in significant reduction or elimination ED diversion.

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STEPS THAT HAVE BEEN PERFORMED:

- **Collected data on**
  - **- patients arrival in ED: day of week and time of day**
  - **- mode of transportation: walk-ins or ambulance**
  - **- discharge disposition: home / expired or admitted in the Hospital**

- **Analyzed LOS distribution and its functional approximation for**
  - **(i) discharged home, and**
  - **(ii) admitted patients**

- **Developed an ED Process Model aimed at modeling different scenarios of LOS upper limits that will result in significant reduction (or elimination) ED diversion**

- **Summarized the basics of modeling methodology: What did we learn ?**

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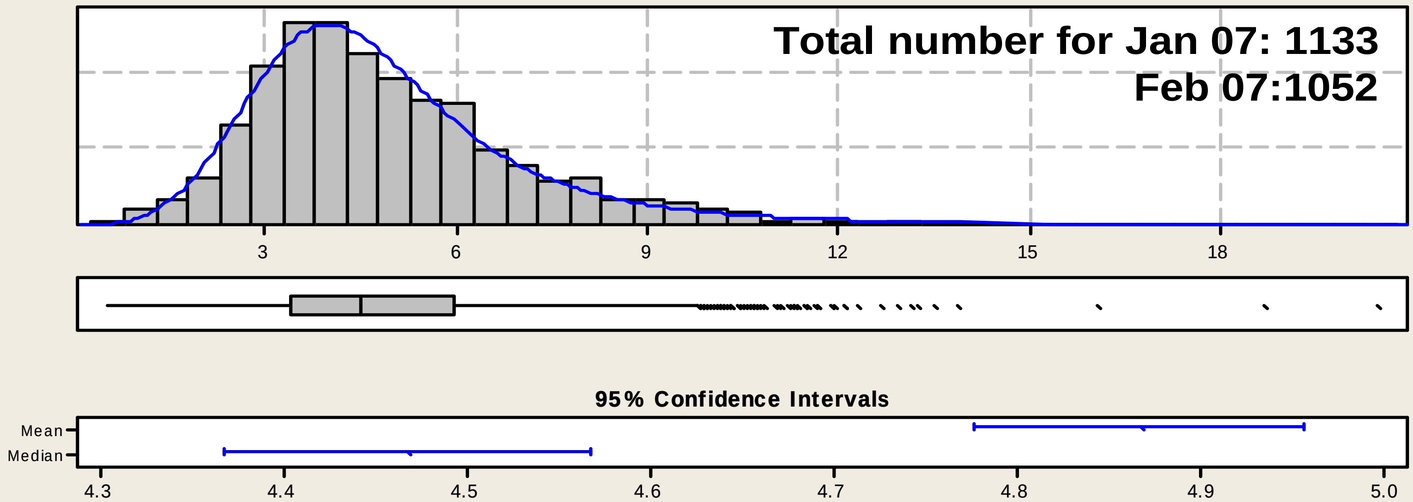
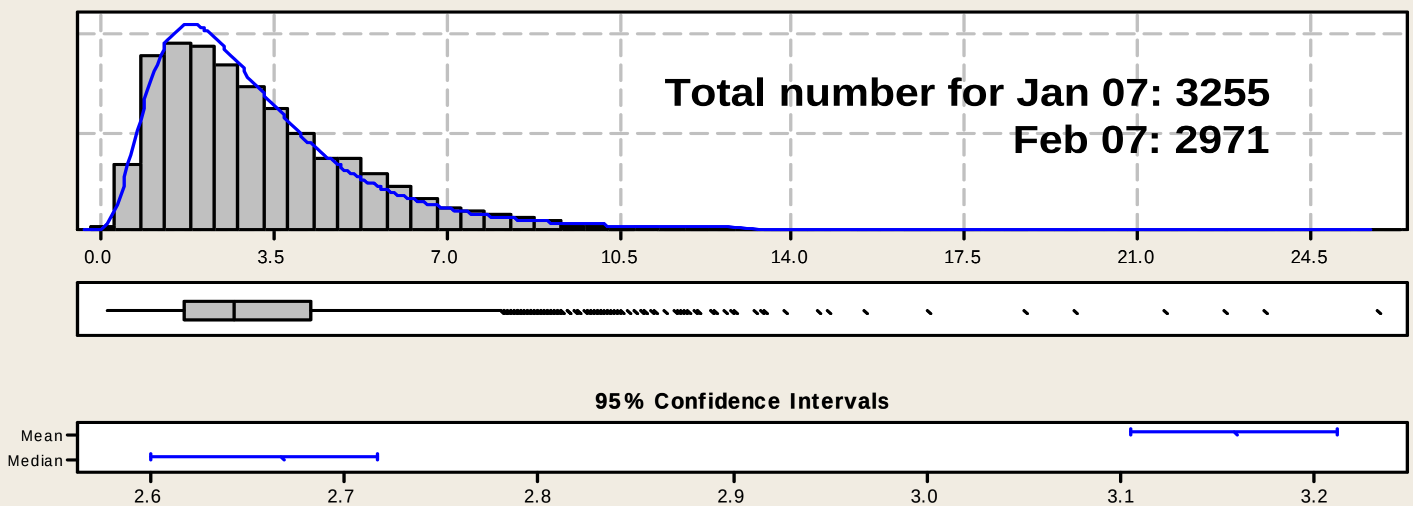
What is the LOS distribution for admitted and discharged home patients ?

Summary for LOS admitted, hrs



Anderson-Darling Normality Test	
A-Squared	32.74
P-Value <	0.005
Mean	4.8654
StDev	2.1305
Variance	4.5389
Skewness	1.22735
Kurtosis	3.14050
N	2185
Minimum	0.4667
1st Quartile	3.3833
Median	4.4667
3rd Quartile	5.9333
Maximum	20.4333
95% Confidence Interval for Mean	
4.7761	4.9548
95% Confidence Interval for Median	
4.3667	4.5667

Summary for LOS home, hrs



Anderson-Darling Normality Test	
A-Squared	146.60
P-Value <	0.005
Mean	3.1569
StDev	2.1225
Variance	4.5051
Skewness	1.84310
Kurtosis	8.14424
N	6155
Minimum	0.0667
1st Quartile	1.6167
Median	2.6667
3rd Quartile	4.2000
Maximum	25.8167
95% Confidence Interval for Mean	
3.1039	3.2099
95% Confidence Interval for Median	

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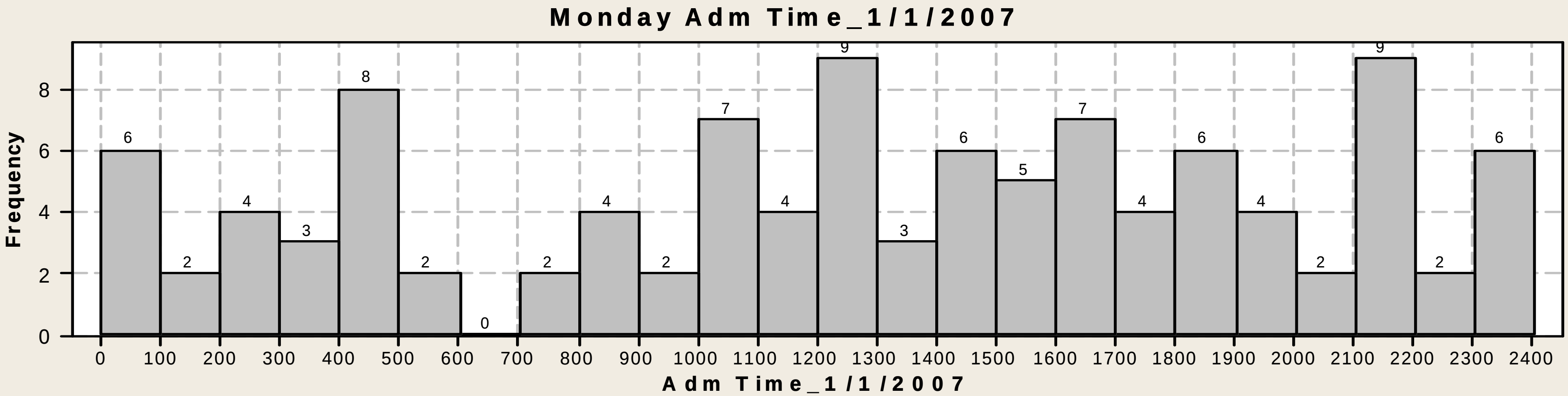
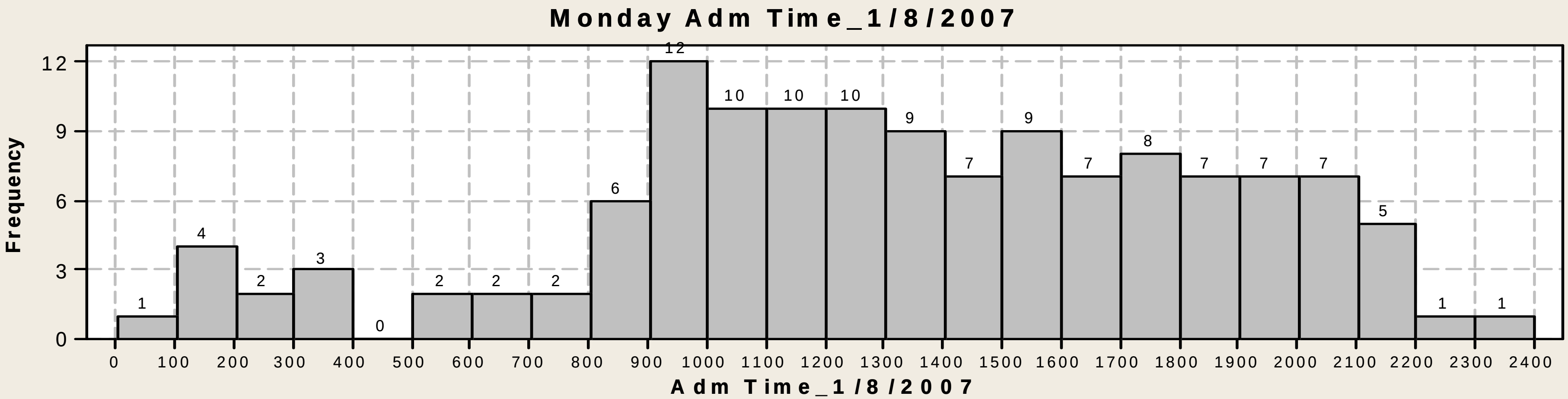
DO THE SAME DAYS OF WEEK FOR DIFFERENT WEEKS HAVE A SIMILAR ARRIVAL PATTERN ?





Take away:

Same days for different weeks have very different patient arrival pattern.

Therefore arrivals for all Mondays, all Tuesdays, and so on should not be combined

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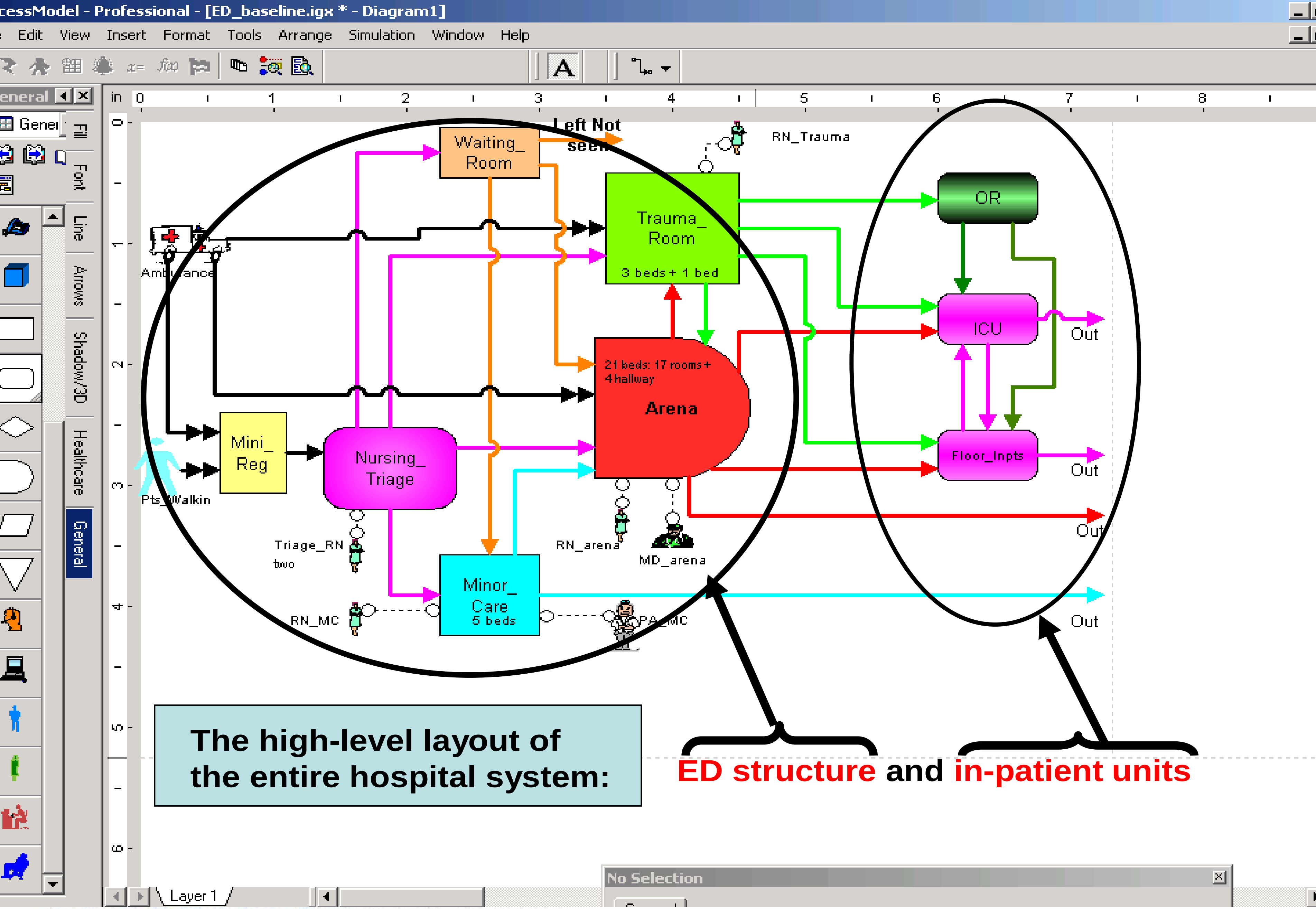
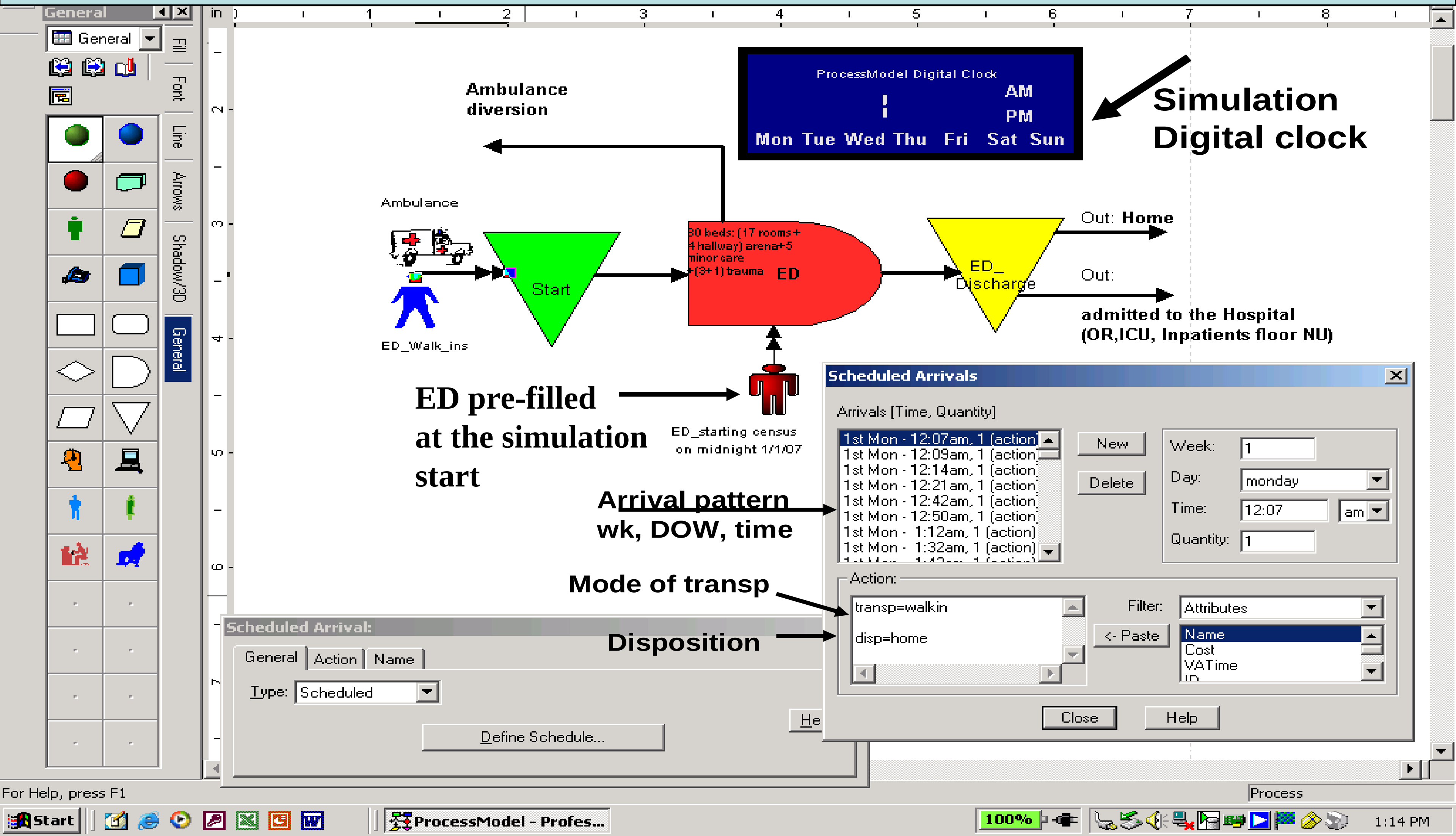


The high-level layout of the entire hospital system:

ED structure and in-patient units

ED simulation model layout



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MODELING APPROACH

- **ED diversion (closure) is declared when ED patients' census reaches ED beds capacity.**

- **ED stays in diversion until some beds become available when patients are moved out of ED (discharged home, expired, or admitted as in-patients).**

- **% ED diversion = % time ED is at full capacity**

- **upper LOS limits (simulation parameters) are imposed on the baseline original LOS distributions:**
LOS higher than the limiting value is NOT allowed in the simulation run.

Take-away:

Baseline LOS distributions should be recalculated as functions of the upper LOS limits.

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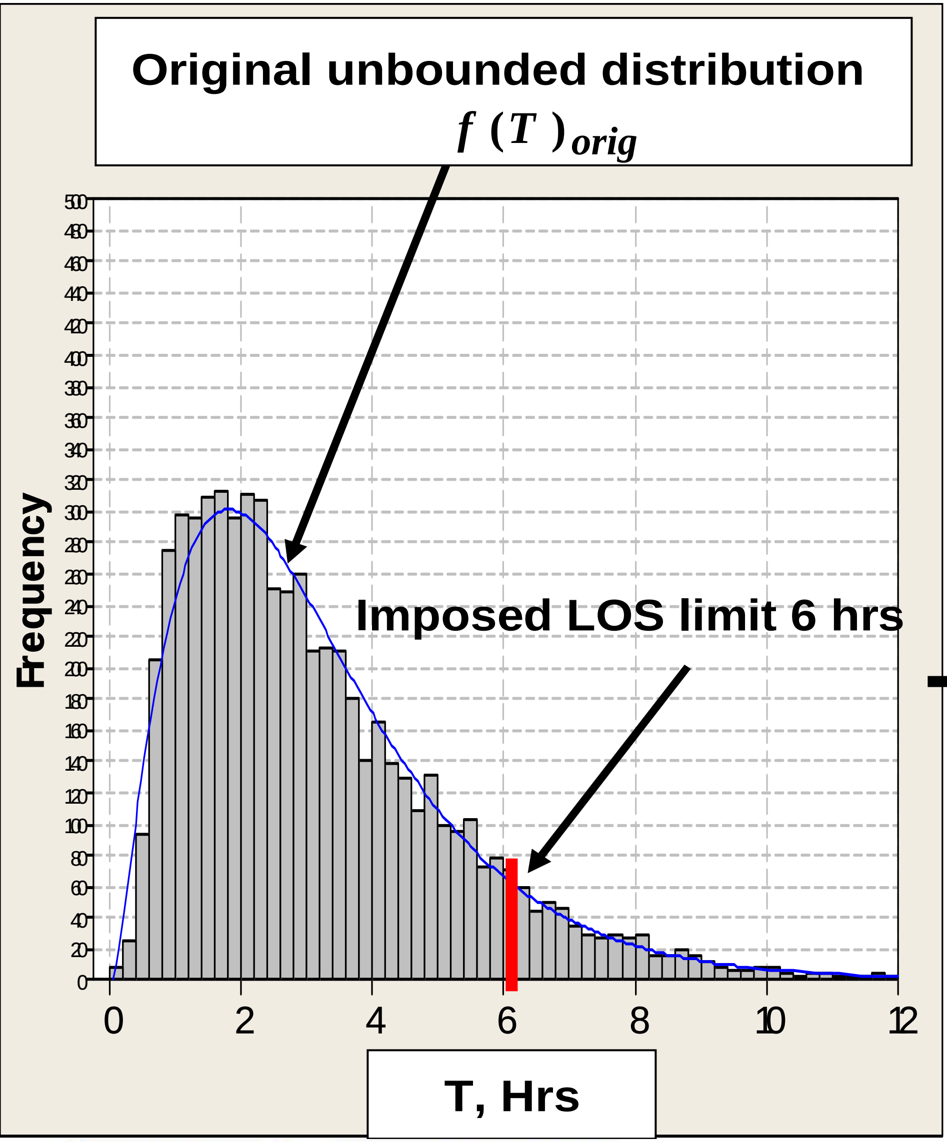
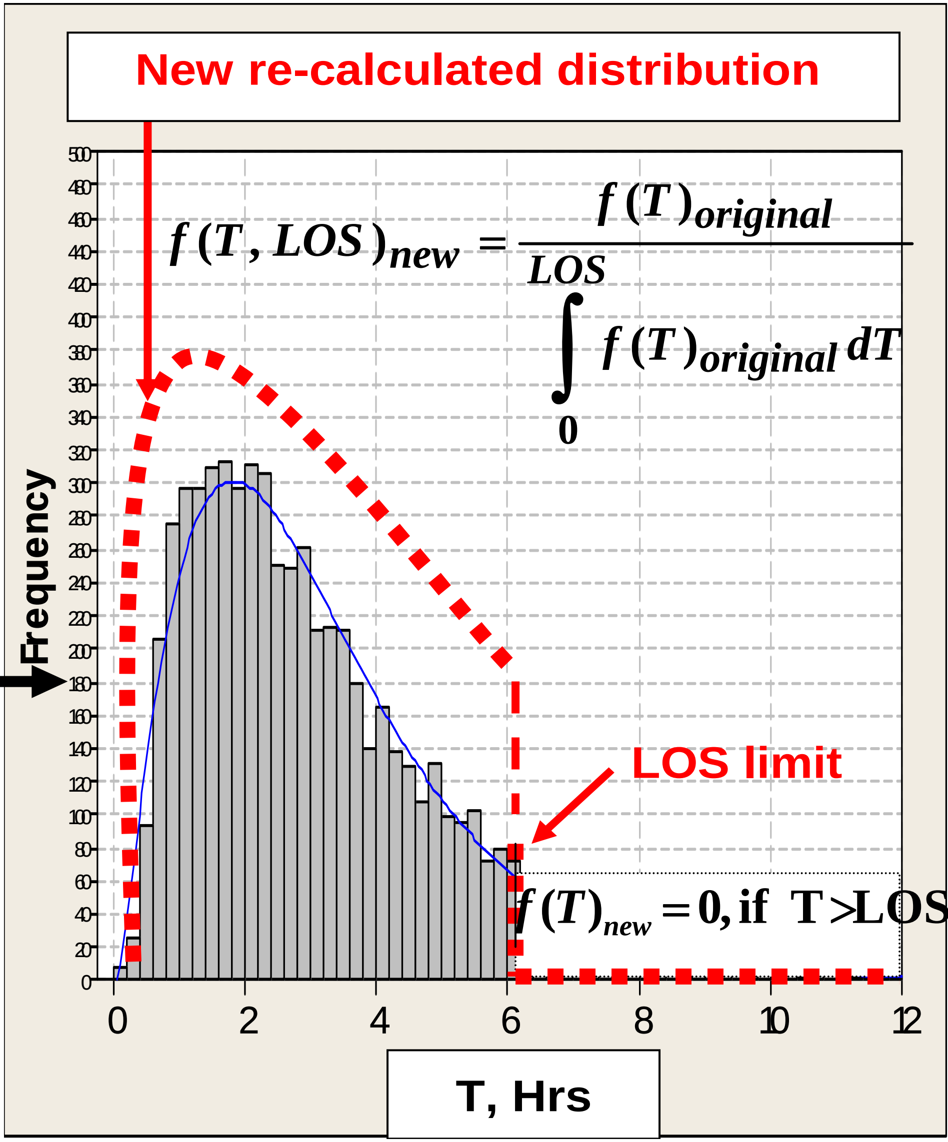
MODELING APPROACH (cont.)

Given original distribution density and the limiting value of the random variable T, what is the conditional distribution of the restricted random variable T ?





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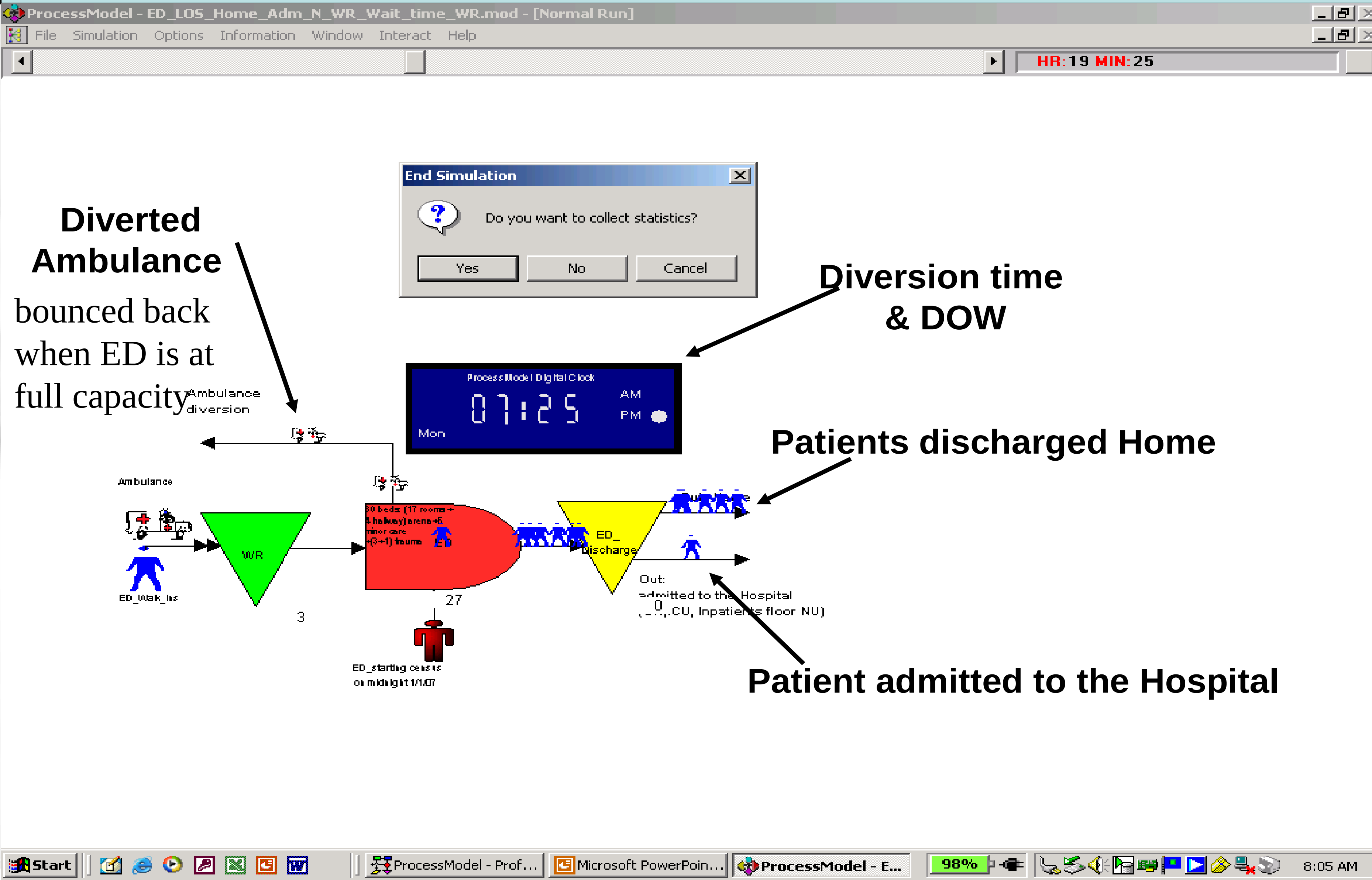
ED Simulation Run Example



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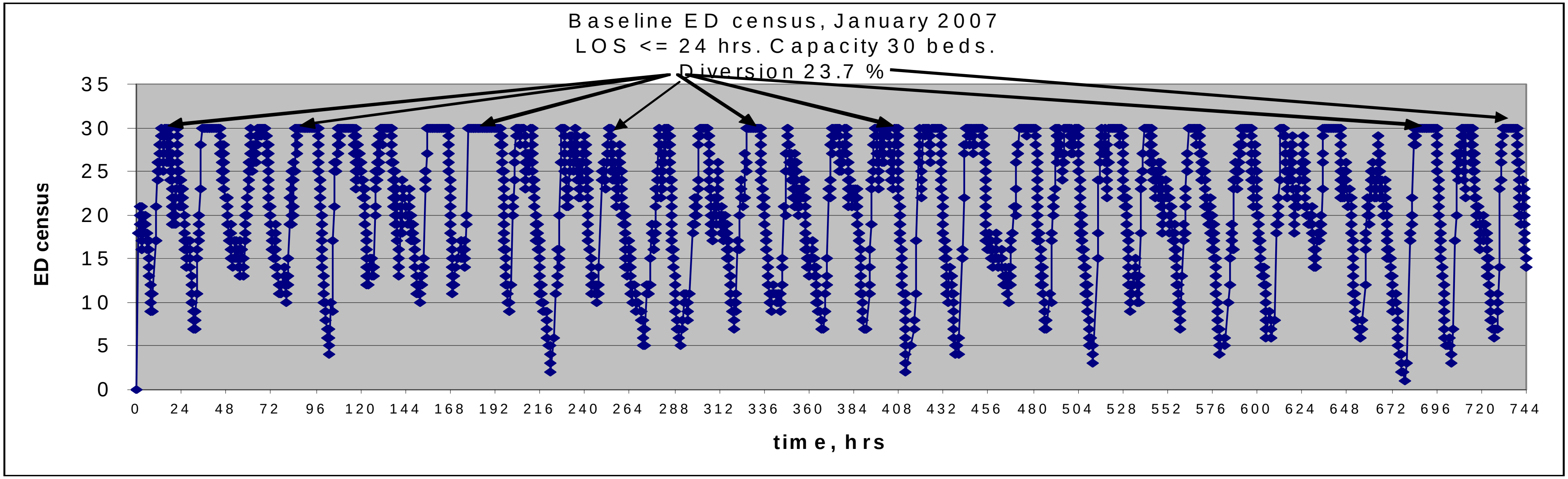
SIMULATION SUMMARY & MODEL VALIDATION

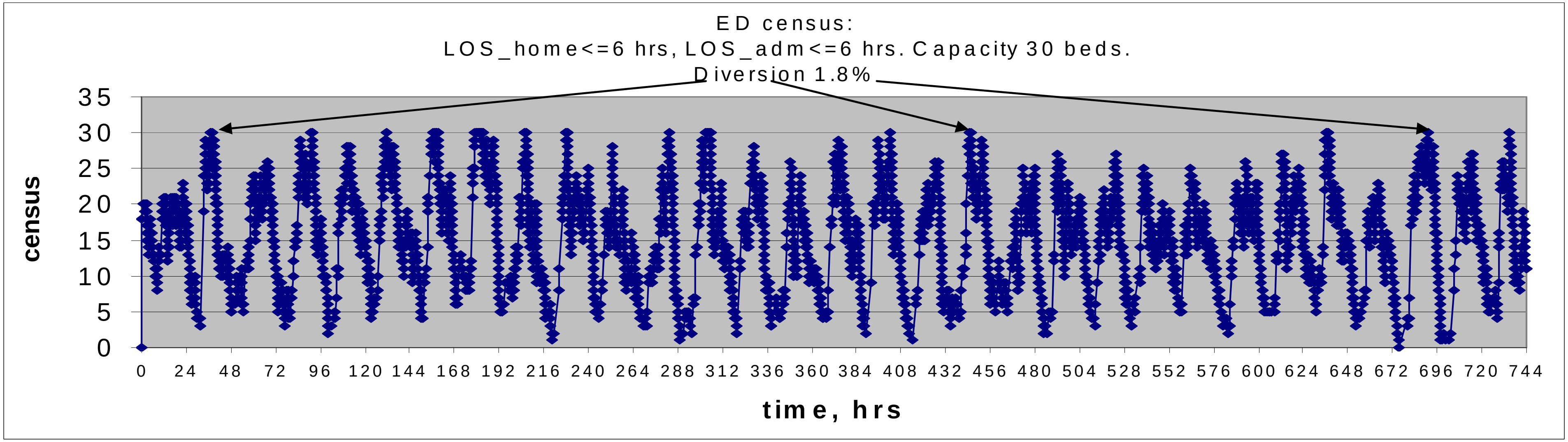
Scenario/option	LOS for discharged home NOT more than	LOS for admitted NOT more than	Predicted ED diversion, %	Note
Current, 07 (Baseline)	24 hrs	24 hrs	23.7%	Actual ED diversion was 21.5%
1	5 hrs Currently 17% with LOS more than 5 hrs;	6 hrs Currently 24% with LOS more than 6 hrs;	~ 0.5 %	Practically NO diversion
2	6 hrs	6 hrs	~ 2%	Low single digits diversion
3	5 hrs	24 hrs	~4%	Low single digits diversion

Take-away:

- ED diversion could be negligible (~0.5%) if patients discharged home stay NOT more than 5 hrs and admitted patients stay NOT more than 6 hrs.
- Relaxing of these LOS limits results in low digits % diversion that still could be acceptable

Diversion is declared when ED census hits capacity limit.
The longer the census stays at capacity limit the higher is diversion %





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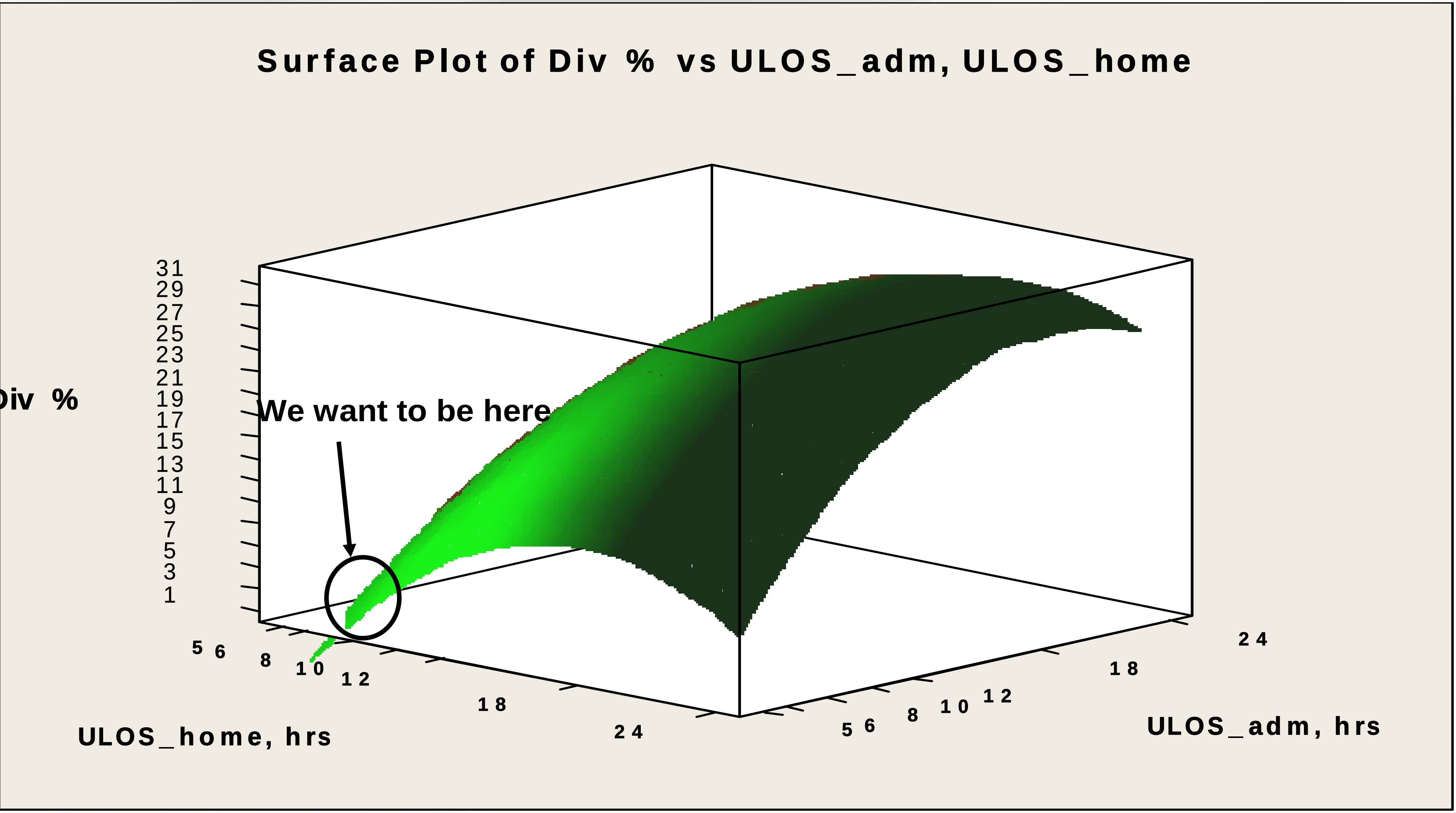
What other combinations of upper limits LOS are possible to get low single digits % ED diversion ?

Performed full factorial DOE with two factors (ULOS_home and ULOS_adm) at 6 levels each using simulated % diversion as a response function.



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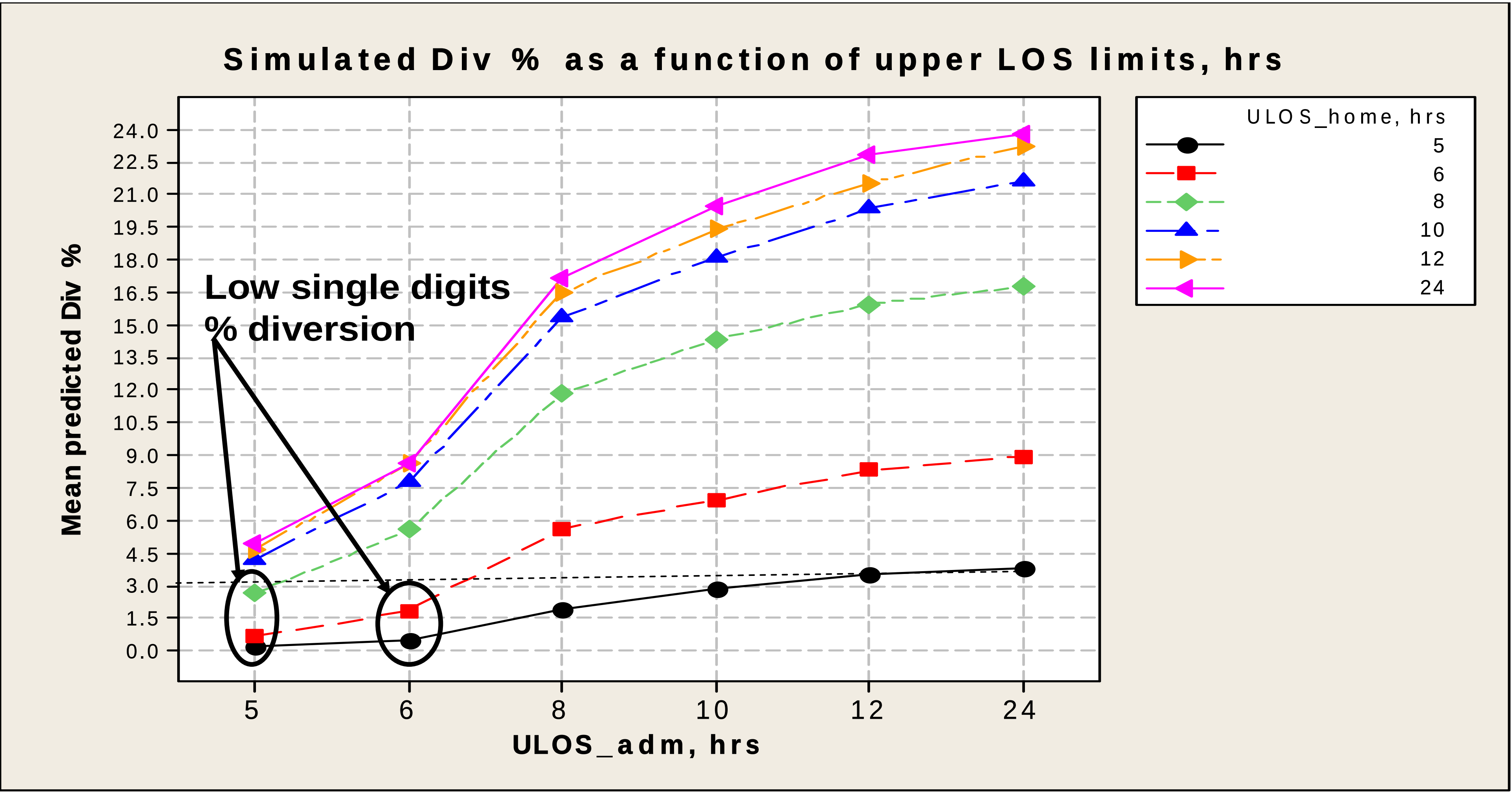
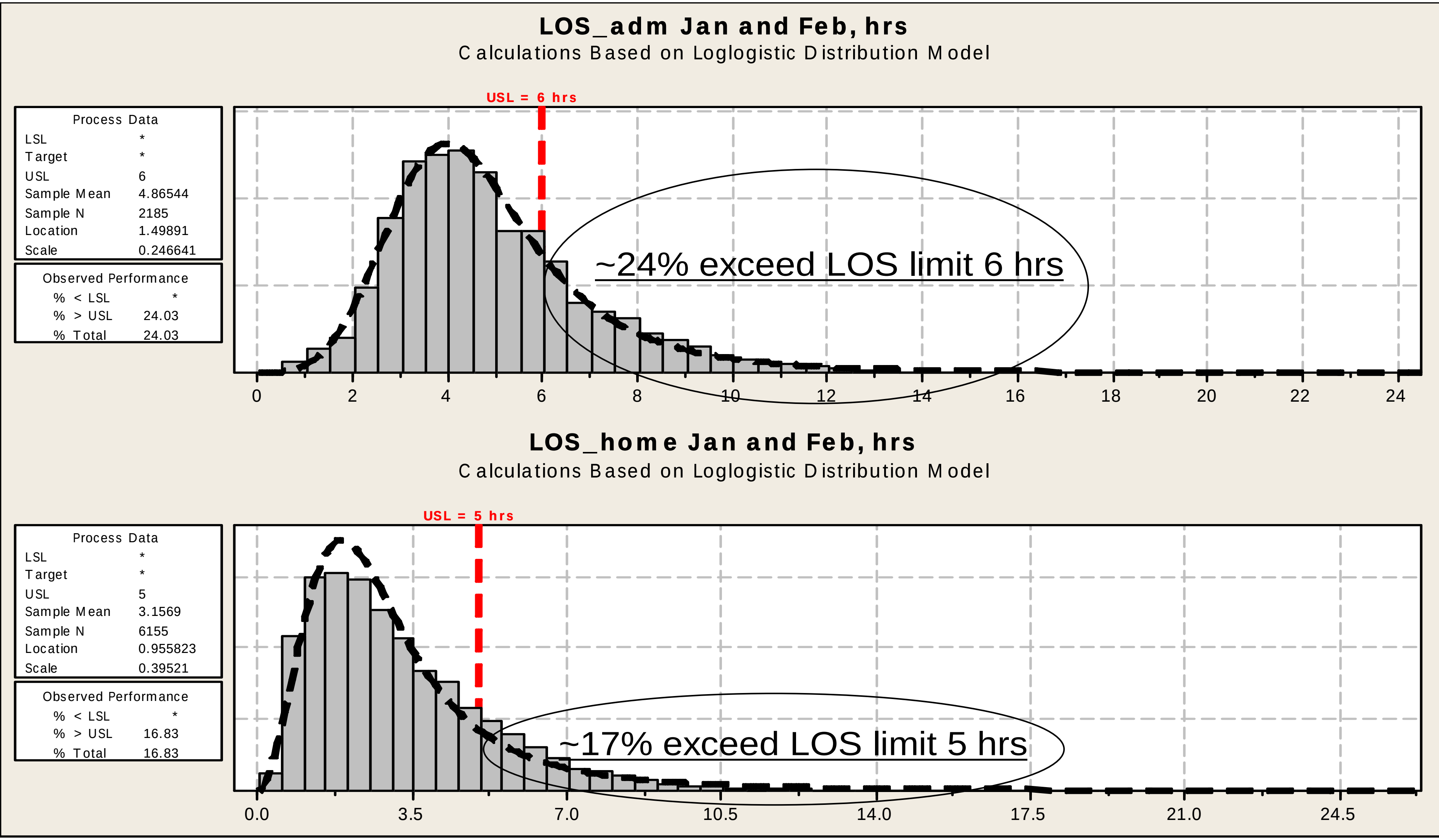


% of patients that stay longer than the upper LOS limit



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ALTERNATIVE CLOSURE CRITERIA

Objectives

1. Maintain Safe Patient Care
2. Decrease ED Diversions
3. Decrease Length of Stay
4. Decrease Left Not Seens

More than X patients waiting for a bed ?

YES → **Evaluate options to create beds**

expedite discharges
move dispo'd pts to off floor bed
move stable pts to non-monitored bed
Advanced Nurse initiatives
Investigate LOS greater than 5 hours
Consult delays?
Radiology delays?
Lab delays?

→ Bed Available?

NO → **CONSIDER CLOSING**

NO ↓

Wait time greater than Y hours ?

YES → **Evaluate options to create beds**

NO ↓

Stay open

Questions to be addressed using Process Model simulation:

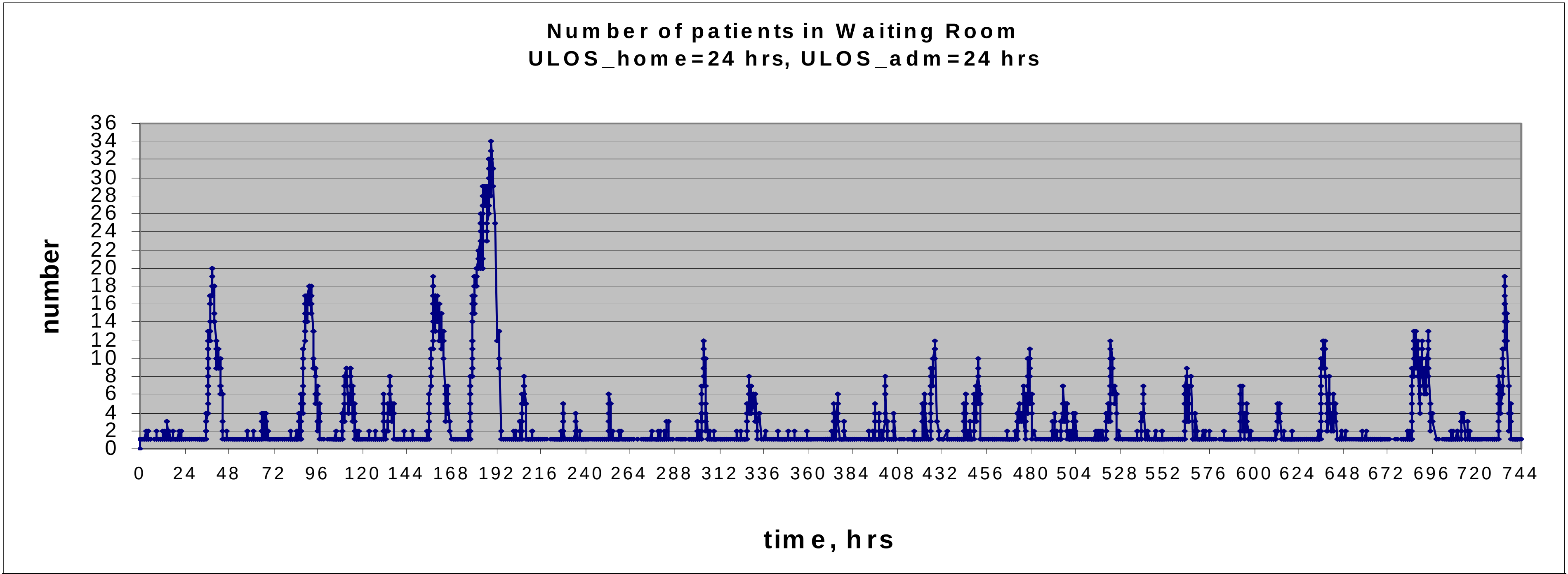
- **What should X and Y be to get low percent diversion ?**
- **Are X and Y correlated ?**

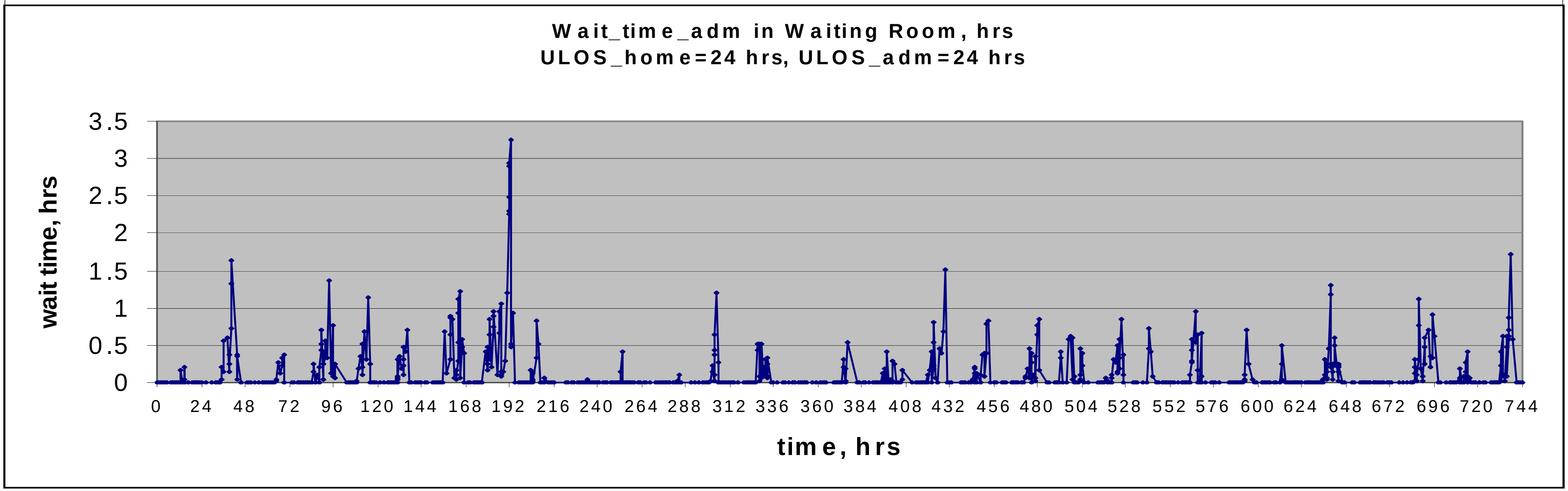
SIMULATION OF ALTERNATIVE CLOSURE CRITERIA

Scenario/option	LOS for discharged home **NOT more than**	LOS for admitted **NOT more than**	Predicted ED diversion, %	**Max** number of patients in **Waiting Room**	Waiting time for admitted patients in **Waiting Room**
Current state, (Baseline)	**24 hrs**	**24 hrs**	**23.7%**	**31**	**3 hr 30 min**
1	**5 hrs**	**6 hrs**	**~ 0.5 %**	**7**	**35 min**
2	**6 hrs**	**6 hrs**	**~ 2%**	**10**	**43 min**
3	**5 hrs**	**24 hrs**	**~4%**	**12**	**1 hr**

Take-away:

- **The lower max number of patients in the waiting room and max waiting time the lower is ED diversion**
- **Locations of peaks of the max number of patients in Waiting Room is strongly correlated to locations of peaks of the max waiting time (see next slides)**





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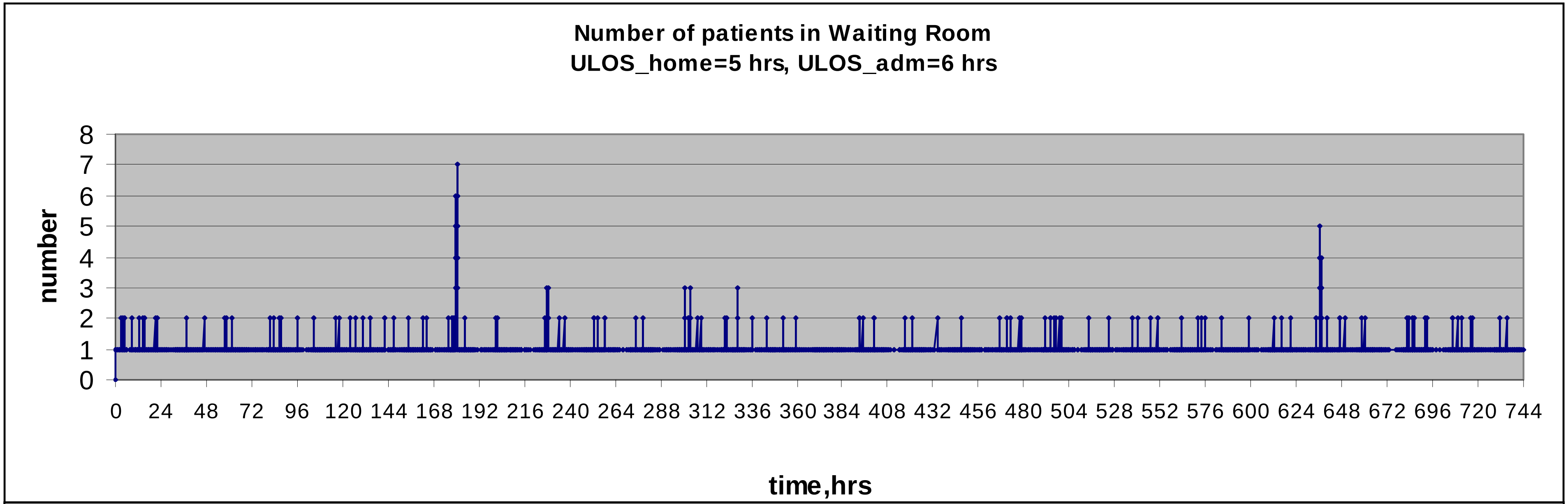

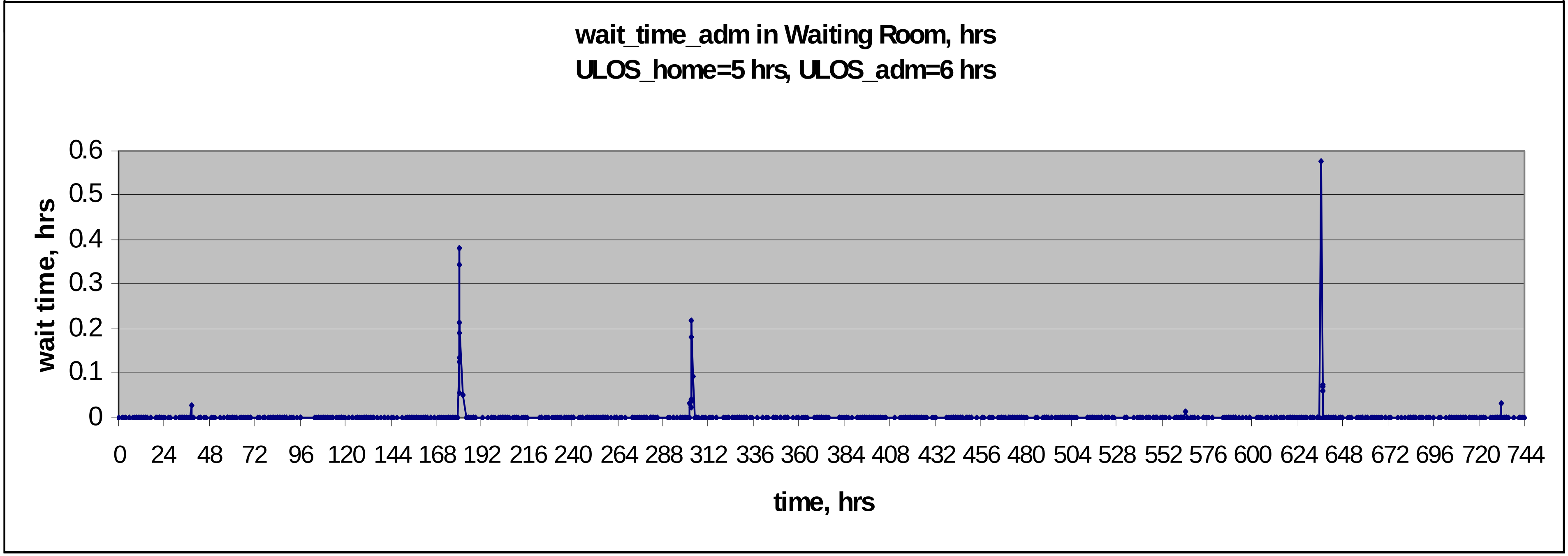

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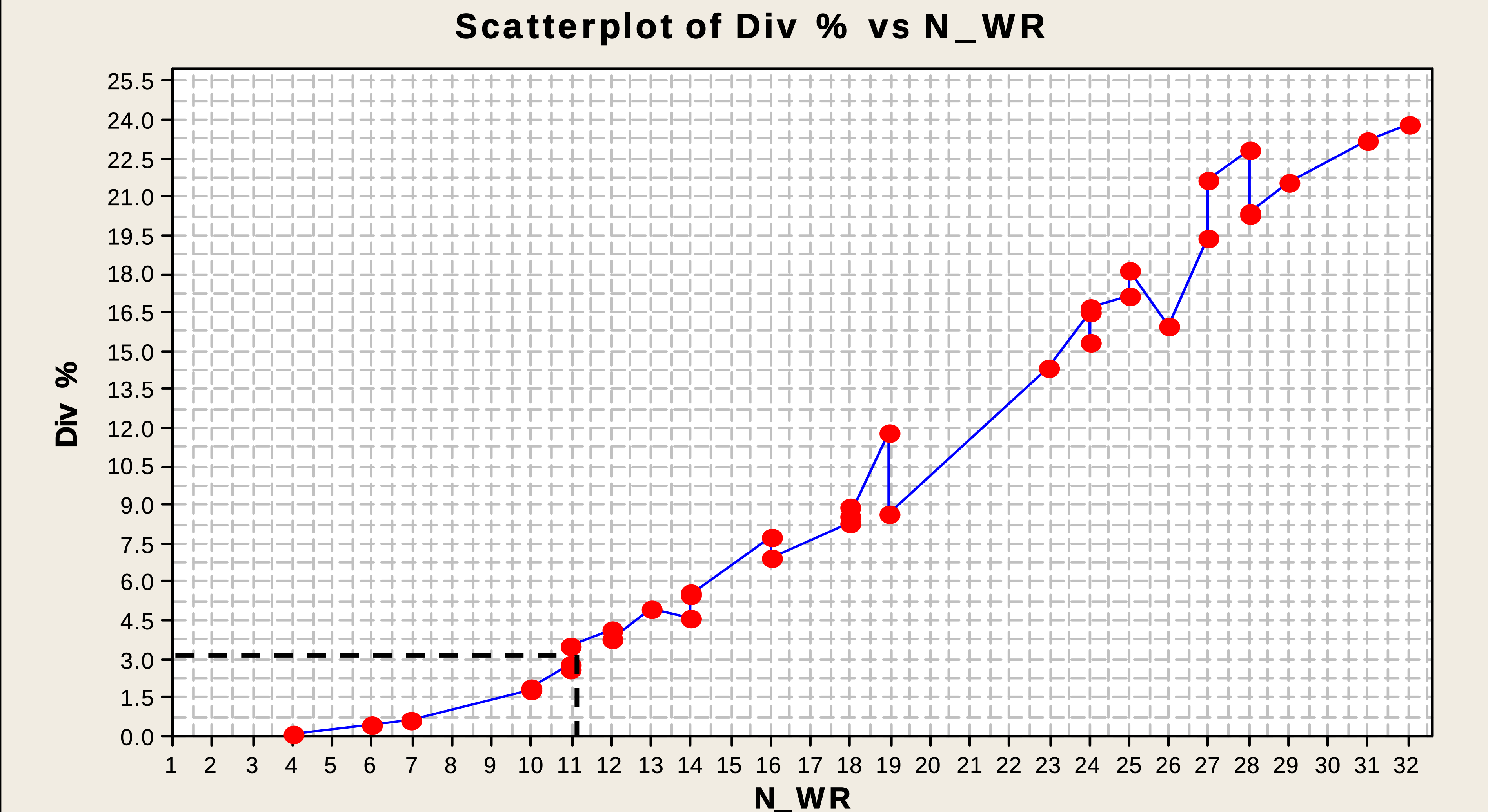

Take-away:

The number of patients in waiting room 11 or less corresponds to single digits diversion less than 3%

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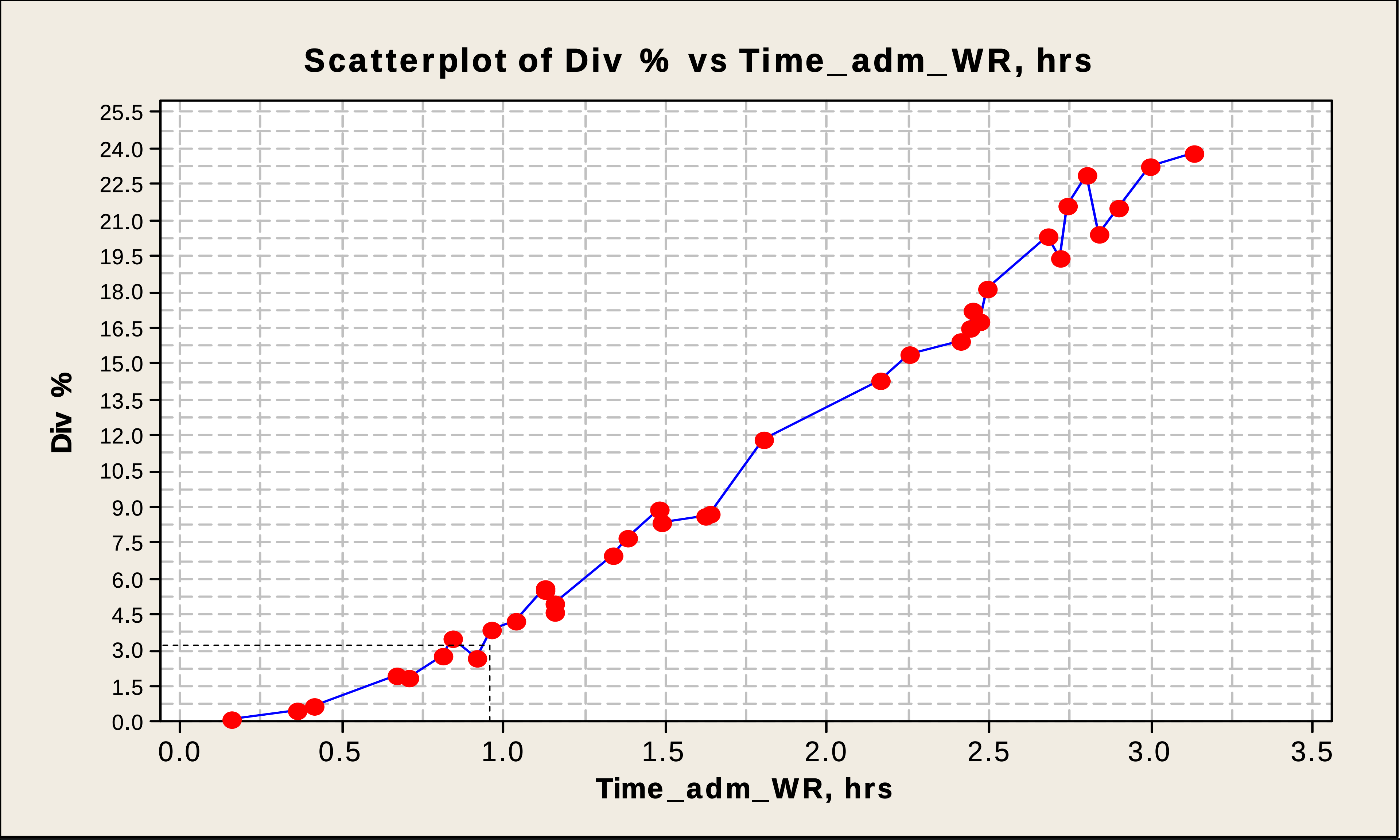

Take-away:

Waiting time for admitted patients in waiting room 1 hr or less corresponds to single digits diversion less than 3%

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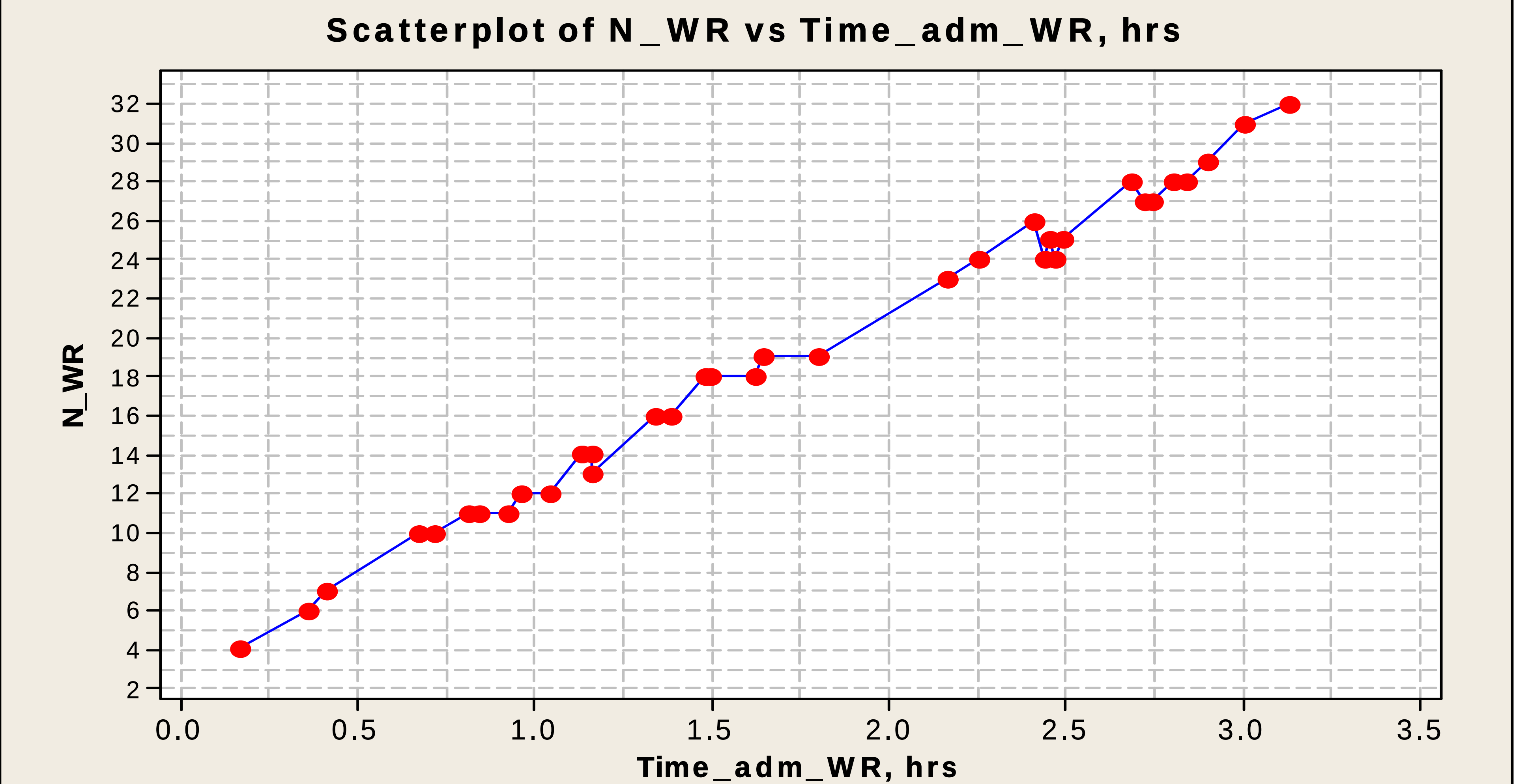

Take-away:

- **The number of waiting patients and the waiting time for admitted patients is <u>strongly correlated</u> to each other. Pearson linear correlation coefficient is <u>0.996 ! !</u>.**
- **Strong correlation indicates that either one or another criteria should be enough, not both.**

Conclusions

• ED diversion could likely be negligible (less than 1 %) if patients discharged home stay **NOT more than 5 hrs** and admitted patients stay **NOT more than 6 hrs**.

Currently:
-17% of patients discharged home stay above this limit up to 24 hrs;
-24 % of admitted patients stay above this limit up to 20 hrs.
This long LOS for large % of patients results in ED closure/diversion

• Some relaxing of these LOS limits will result in low single digits % ED diversion that still could be acceptable

• Other combinations of **LOS upper limits** that result in low single digits % diversion have been determined using full factorial DOE with two factors.

• An alternative diversion criteria could be used: the number of patients in waiting room. The number of patients **11 or less** corresponds to single digits diversion, less than ~3%

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What did we learn about simulation methodology?

- Patient Throughput flow is an example of the general Dynamic Supply & Demand problem .
  Dynamic means that the system's behavior depends on time (not a one-time snapshot)

- There are three basic components that should be accounted for in this type of problems:
  - The number of patients (or, generally, any items) entering the system at any point of time
  - The number of patients (any items) leaving the system at any point of time
  - Limited Capacity of the system which limits the flow of patients through the system

- All three components affect the flow of patients that the system can handle.

- A lack of the proper balance between these components results in the system's over-flow and closure/diversion

- **Process Model Simulation methodology provides the only means of analyzing and managing the proper balance**

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APPENDIX

WHAT IS THE PROCESS MODEL ?

- **It is a computer model that mimics the dynamic behavior of a real process over the time in order to visualize and quantitatively analyze its performance in terms of:**
  - **Cycle times**
  - **Throughput capacity**
  - **Resources utilization**
  - **Activities utilization**

- **It is a tool to perform 'WHAT-IF' analysis and play different scenarios of the model behavior as conditions and process parameters change.**

This allows to make experiments on the computer model, and test different solutions (changes) for their effectiveness before going to the floor for the actual implementation.

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WHAT ARE THE BASIC ELEMENTS OF THE PROCESS MODEL?

•**Flow chart of the process:** Diagram that depicts logical flow of a process from its inception to its completion

•**Entities:** Items to be processed: patients, documents, customers, etc.

•**Activities:** Tasks performed on entities: medical procedures, document approval, customer check out, etc

•**Resources:** Agents used to perform activities and move entities: service personnel, operators, equipment, nurses, physicians.

•**Connections:**

•**Entity arrivals:** Define process entry points, time, and quantities of the entities that enter the system to begin processing

•**Entity routings**: Define directions and logical conditions flow for entities

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WHAT INFORMATION (DATA) IS REQUIRED TO FEED THE MODEL ?

•**Entities quantities and arrival time: periodic, random, scheduled, daily pattern, etc**

•**The time that the entities spend in the activities. This is usually not a fixed time but a statistical distribution. The wider the time distribution the higher the variability of the system behavior.**

•**The capacity of each activity, i.e. the max number of entities that can be processed concurrently in the activity.**

•**The size of input and output queues for the activities**

•**The routing type or the logical conditions to take a specified routing.**

•**Resource Assignments: their number and availability, and/or resources shift schedule**