

Processing Networks, PERT

- Def. Fork-Join Networks (p.2-3)
- EX1. A Generic ED Processing Network (p. 4-10)
- EX2. Call Center – Realization (p. 11)
- Analyzing a Fork-Join Network (p. 12-24)

Fork-Join Networks

- A **fork-join network**
 - consists of a group of service stations
 - serves arriving customers simultaneously and sequentially according to precedence constraints
 - distinguishing features: "fork" and "join"
 - **fork**: occurs whenever several tasks are being processed simultaneously; represented by a "splitting" of a task into multiple tasks
 - **join**: a task that may not be initiated until several prerequisite tasks have been completed; joined only if they correspond to the same job
 - We model our **fork-join network** using **4 flow-charts**
 - Activities, resources, activities plus resources, and information

Fork-Join Networks (2)

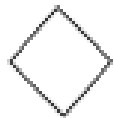
- Flow-chart legend



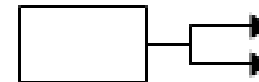
Activity / Resource



Job's "flow"



Decision



"Fork"



Resources queue



"Join"



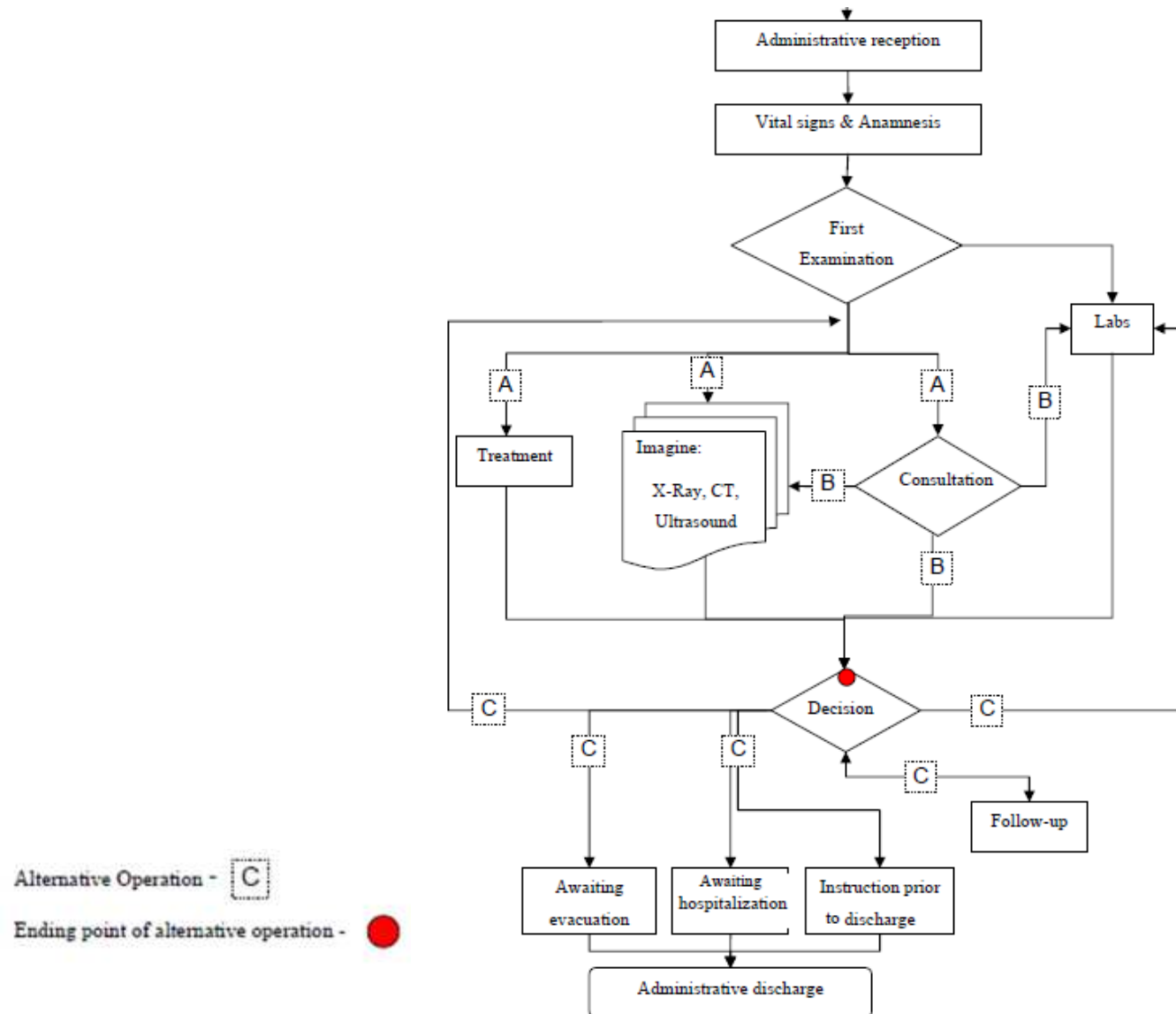
Synchronization queue

EX1. A Generic ED Processing Network

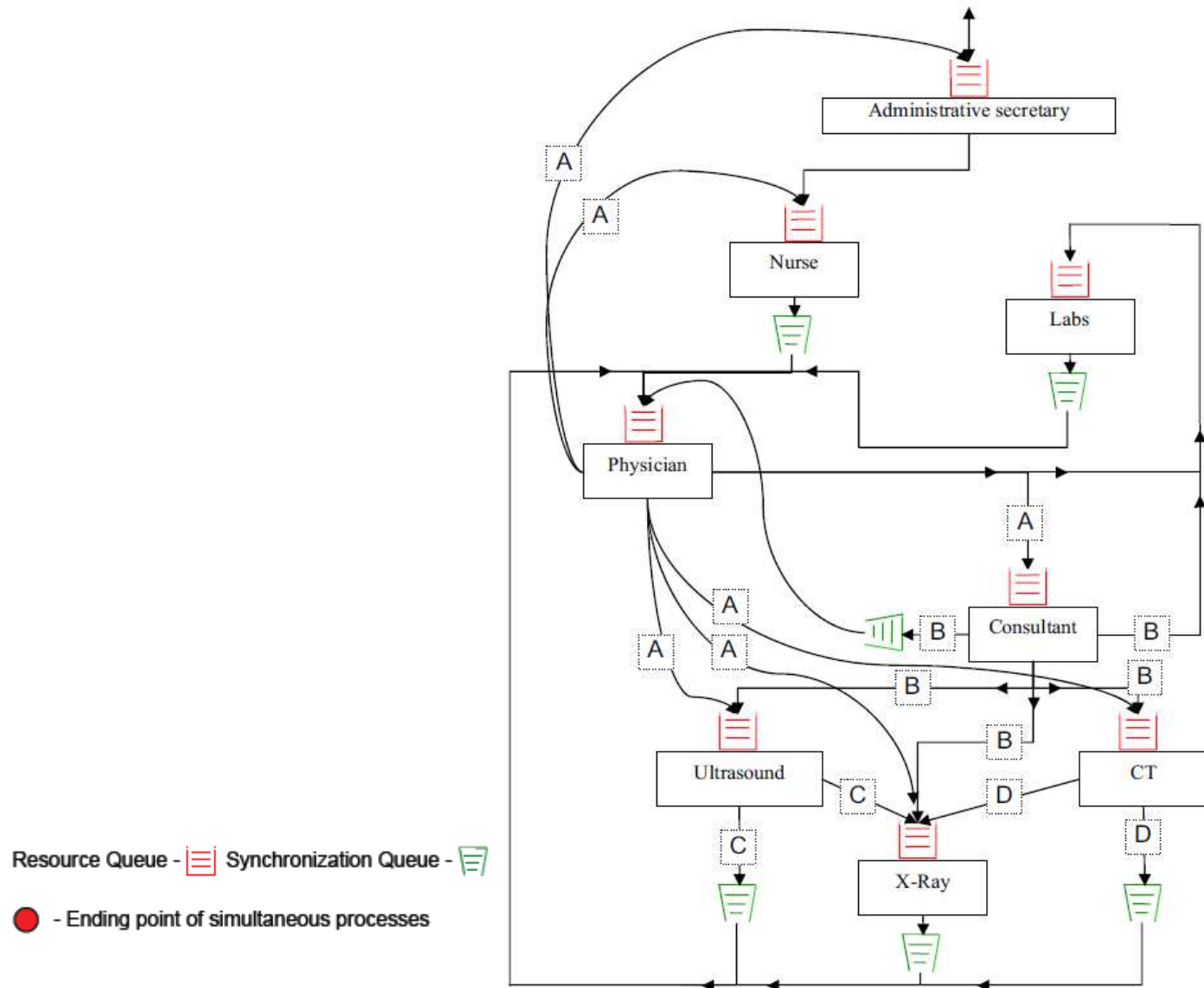


Activity	Resource
Administrative Reception	Secretary
Vital Signs and Anamnesis	Nurse
First Examination	Physician
Treatment (Physician)	Physician
Treatment (Nurse)	Nurse
Imaging	X-Ray, CT, Ultrasound
Labs	Lab
Consultation	External
Decision	Physician
Follow-Up	Nurse
Instruction Prior to Discharge	Nurse
Administrative Release	Secretary

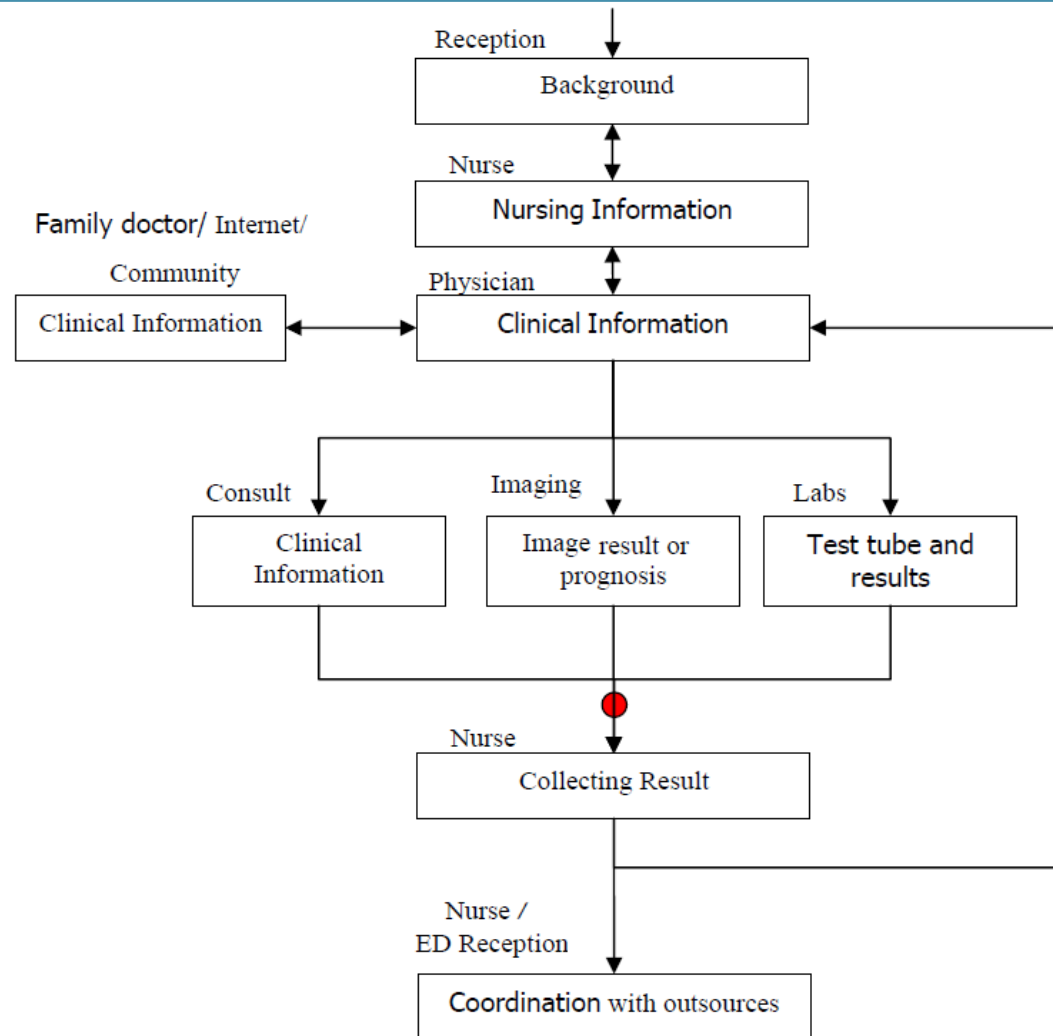
EX1. Activities Flow Chart



EX1. Resources Flow Chart

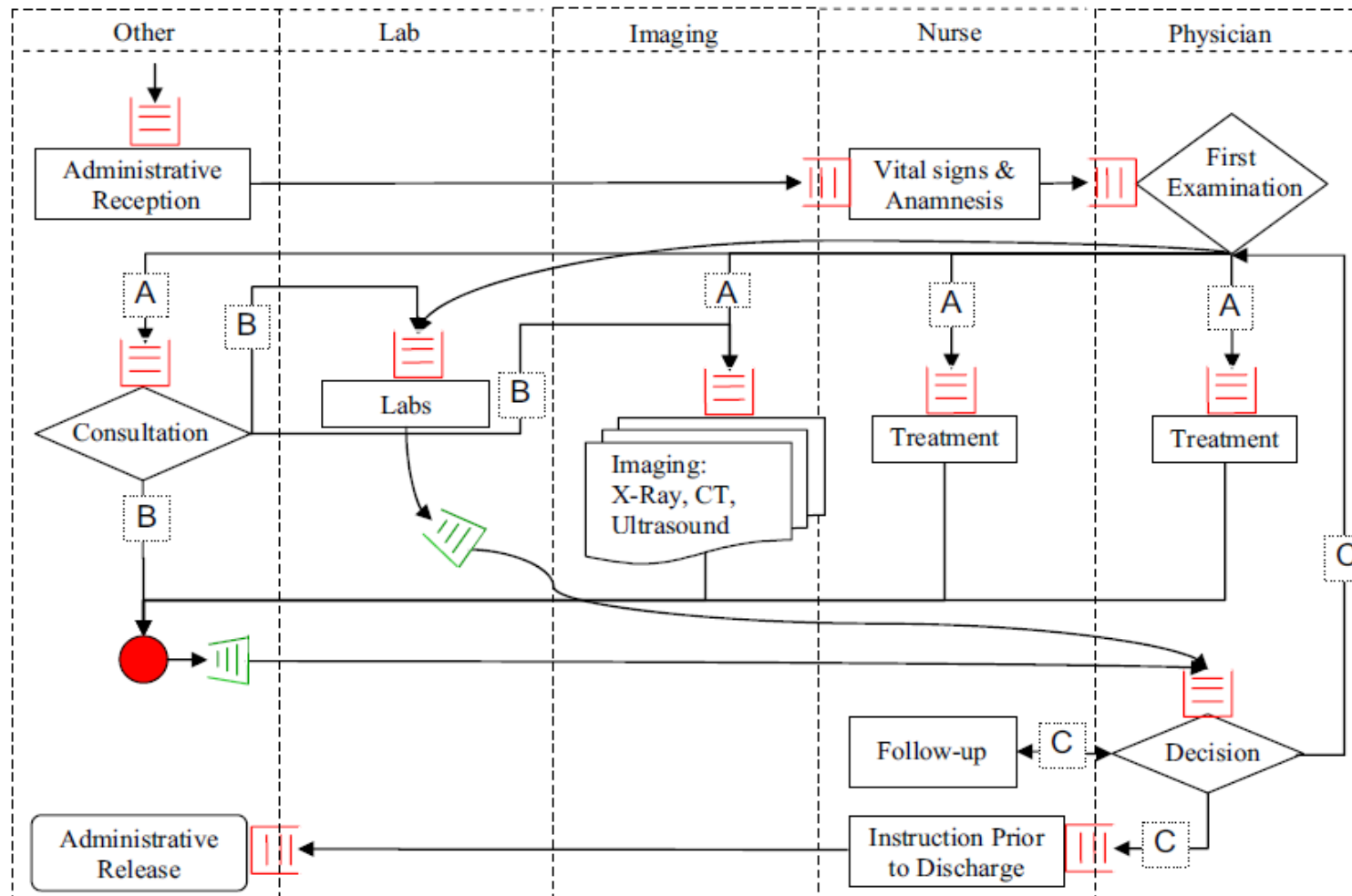


EX1. Information Flow Chart



Ending point of alternative operation - ●

EX1. Activities and Resources Flow Chart



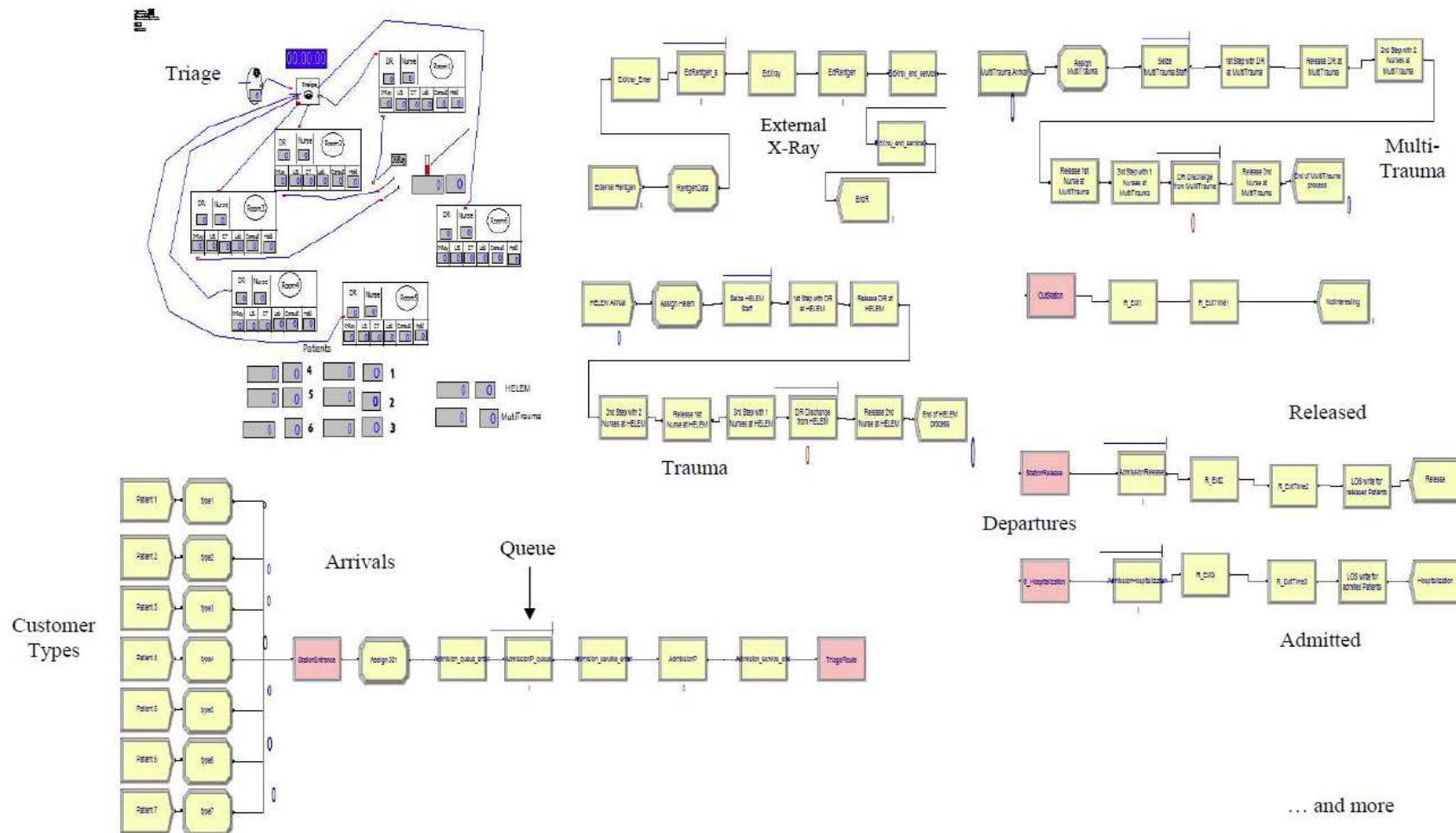
Alternative Operation - C

Recourse Queue -  Synchronization Queue - 

Ending point of alternative operation - ●

EX2. ED Simulator (Arena)

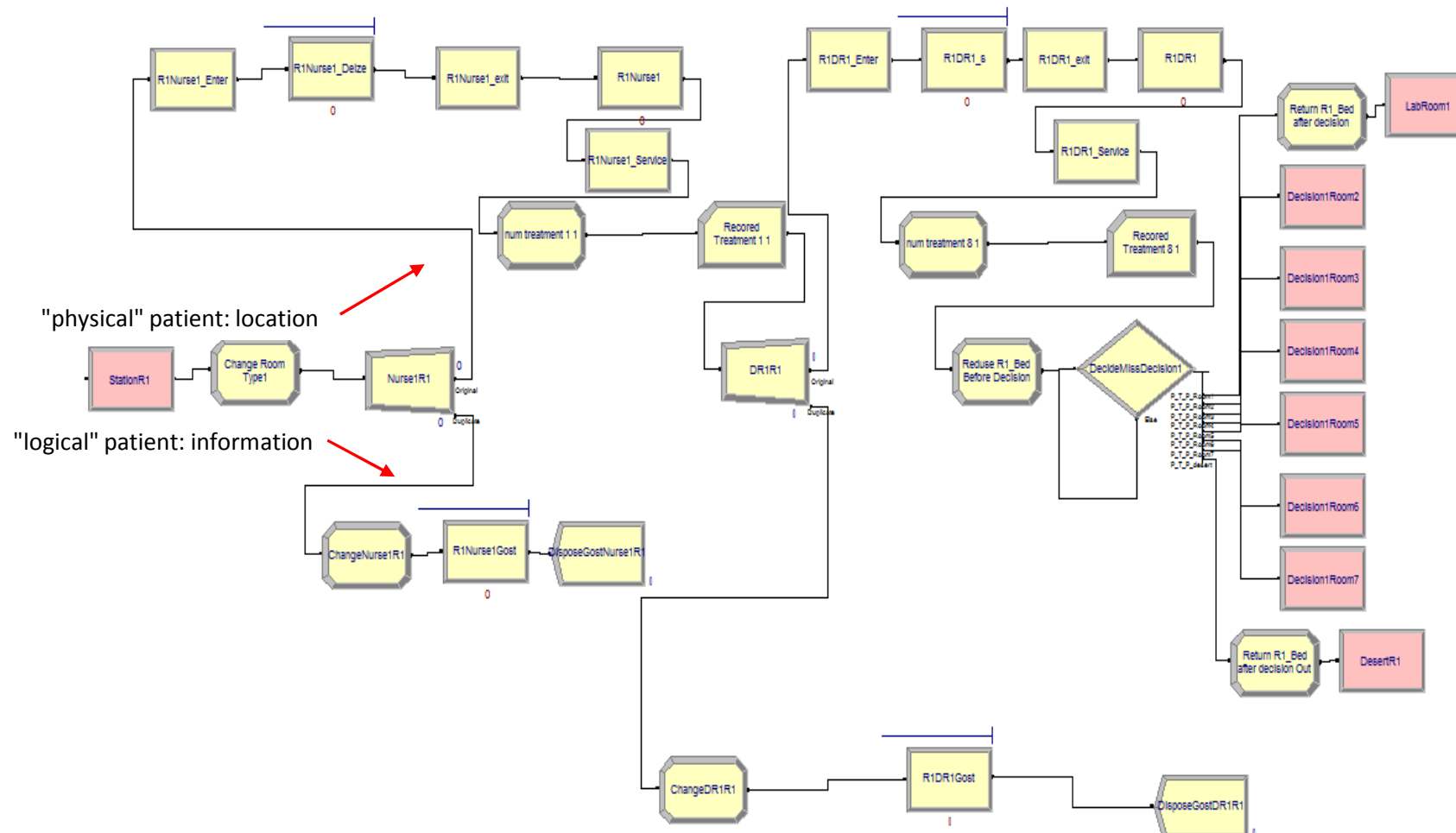
- Used to Calculate Operational Measures



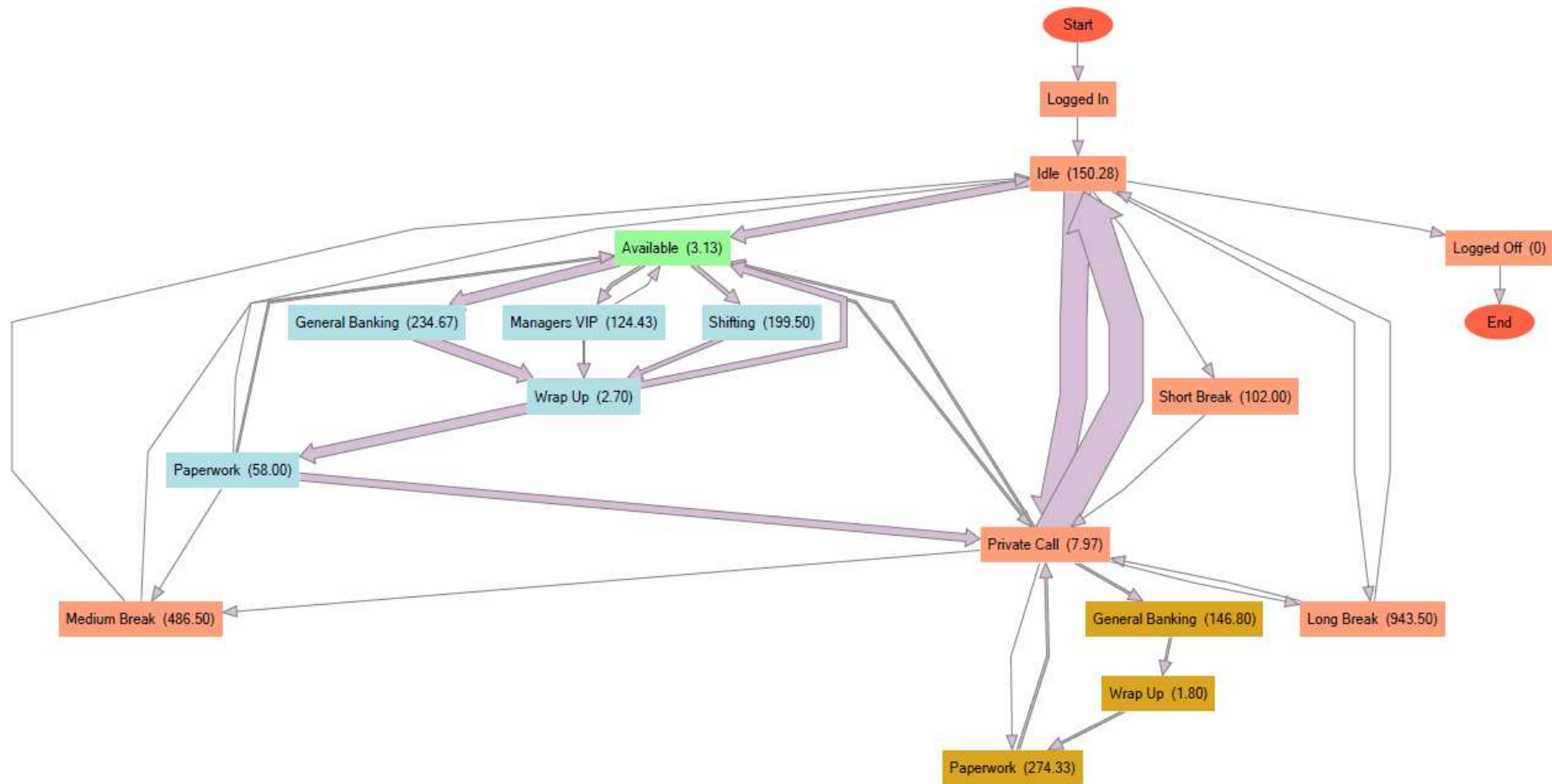
... and more

EX1. ED Simulator (Arena)

- Zoom on Room 1:



EX2. Resource's Activities - Realization



Analyzing a Fork-Join Network

1. Can we do it?
 - via “Capacity Analysis”
2. How long will it take?
 - via “Response-Time Analysis”
3. Can we do better?
 - via “Parametric / Sensitivity (What-If) Analysis”
4. What is the best we (one) can do?
 - via “Optimization”

Q1. Can we do it? (1)

- Average (Weekly) amount of capacity needed:

Needed Staffing	Number Needed	Staffed	Utilization
Internal Dr.	2.32	3.33	70%
Orthopedic Dr.	0.92	1.33	69%
Surgical Dr.	0.44	1	44%
Internal Nurse.	1.59	3	53%
Surgical Nurse.	0.92	1.67	55%

- Details of Calculations:
 - Number Needed: total amount of Offered Load over one day / 24
 - Staffed: total amount of doctor/nurse hours over one day / 24
 - Utilization: Number Needed / Staffed
- NOTE: Utilization is calculated as the average over the whole day. The utilization during loaded hours is much higher (e.g., at 13:30-14:30, utilization of Internal Doctors is 94%)

Q1. Can we do it? (2)

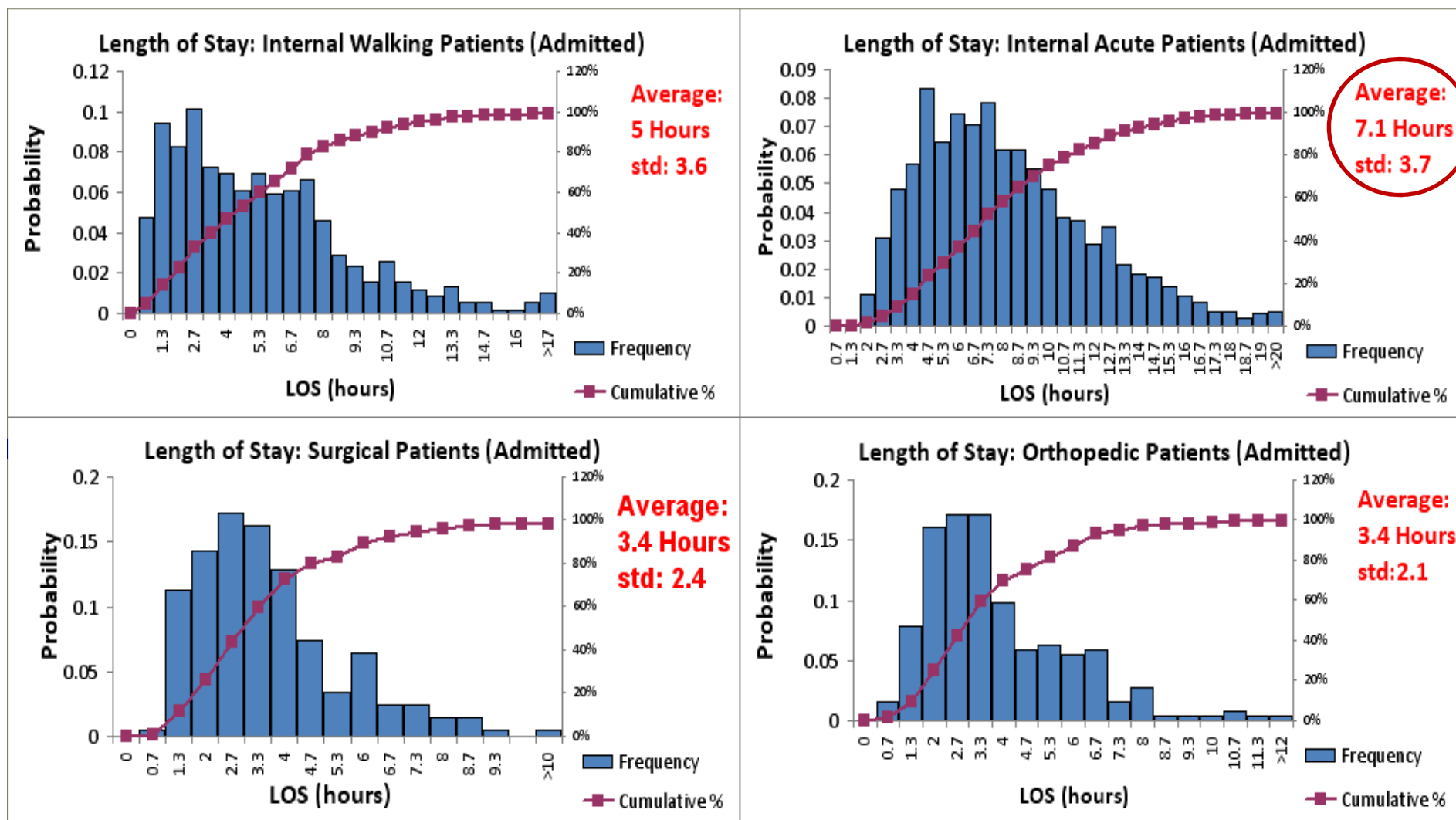
- Current staffing

Time	Internal DR Acute	Internal DR Walking	Surgical DR	Orthopedic DR	Internal Nurse Acute	Internal Nurse Walking	Surgical Nurse
0:00	1	2	1	1	1	2	1
1:00	1	2	1	1	1	2	1
2:00	1	2	1	1	1	2	1
3:00	1	2	1	1	1	2	1
4:00	1	2	1	1	1	2	1
5:00	1	2	1	1	1	2	1
6:00	1	2	1	1	1	2	1
7:00	1	2	1	1	1	2	2
8:00	1	3	1	2	1	2	2
9:00	1	3	1	2	1	2	2
10:00	1	3	1	2	1	2	2
11:00	1	3	1	2	1	2	2
12:00	1	3	1	2	1	2	2
13:00	1	3	1	2	1	2	2
14:00	1	3	1	2	1	2	2
15:00	1	3	1	2	1	2	2
16:00	1	2	1	1	1	2	2
17:00	1	2	1	1	1	2	2
18:00	1	2	1	1	1	2	2
19:00	1	2	1	1	1	2	2
20:00	1	2	1	1	1	2	2
21:00	1	2	1	1	1	2	2
22:00	1	2	1	1	1	2	2
23:00	1	2	1	1	1	2	1

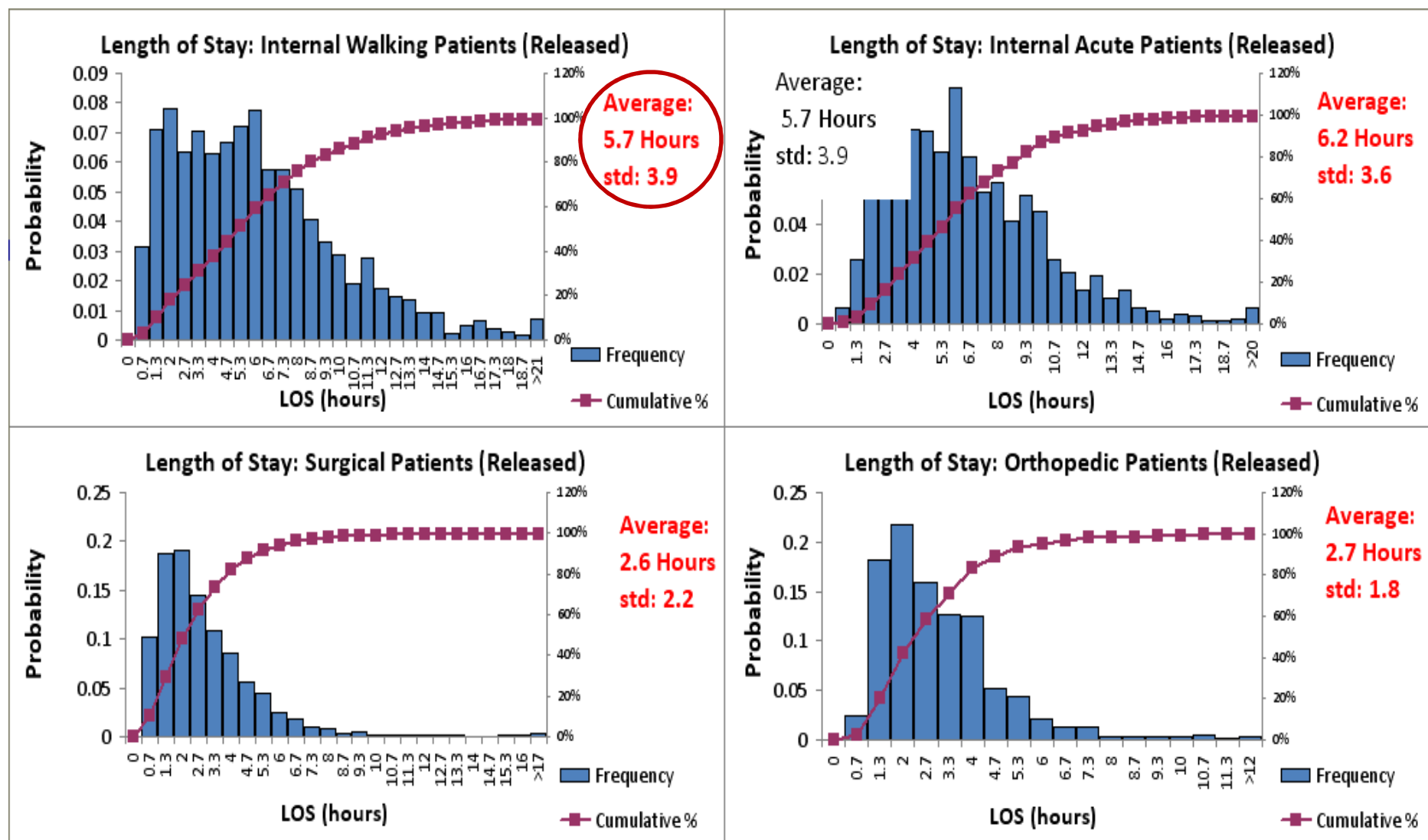
Q2. How long with it take?

- 8 types of patients
 1. **Walking Internal Patients – Admitted to hospital**
 2. Walking Internal Patients – Discharged
 3. Acute Internal Patients – Admitted to hospital
 4. Acute Internal Patients - Discharged
 5. Surgical Patients – Admitted to hospital
 6. Surgical Patients - Discharged
 7. Orthopedic Patients – Admitted to hospital
 8. Orthopedic Patients - Discharged

Q2. Patient's Length of Stay

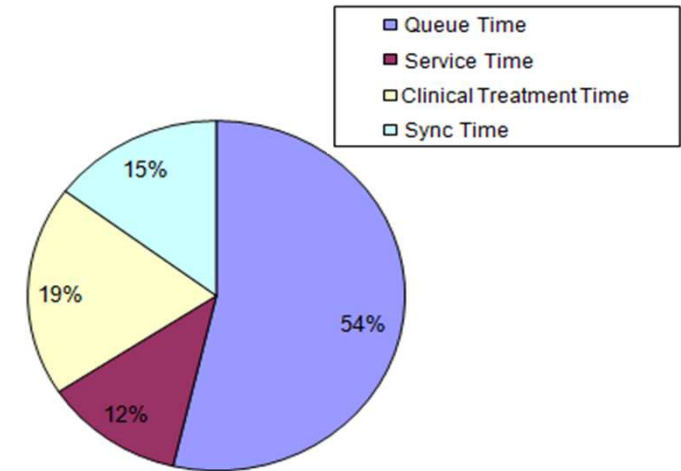


Q2. Patient's Length of Stay (2)



Q2. Anatomy of Sojourn-Time

- **Queue time**: waiting for resource (e.g., doctor)
- **Service time**: duration of service (treatment)
- **Clinical treatment time**: waiting for a medicine to take effect, an X-Ray to develop etc.
- **Sync time**: waiting in a synchronization queue (waiting for lab results before a doctor can begin treatment)

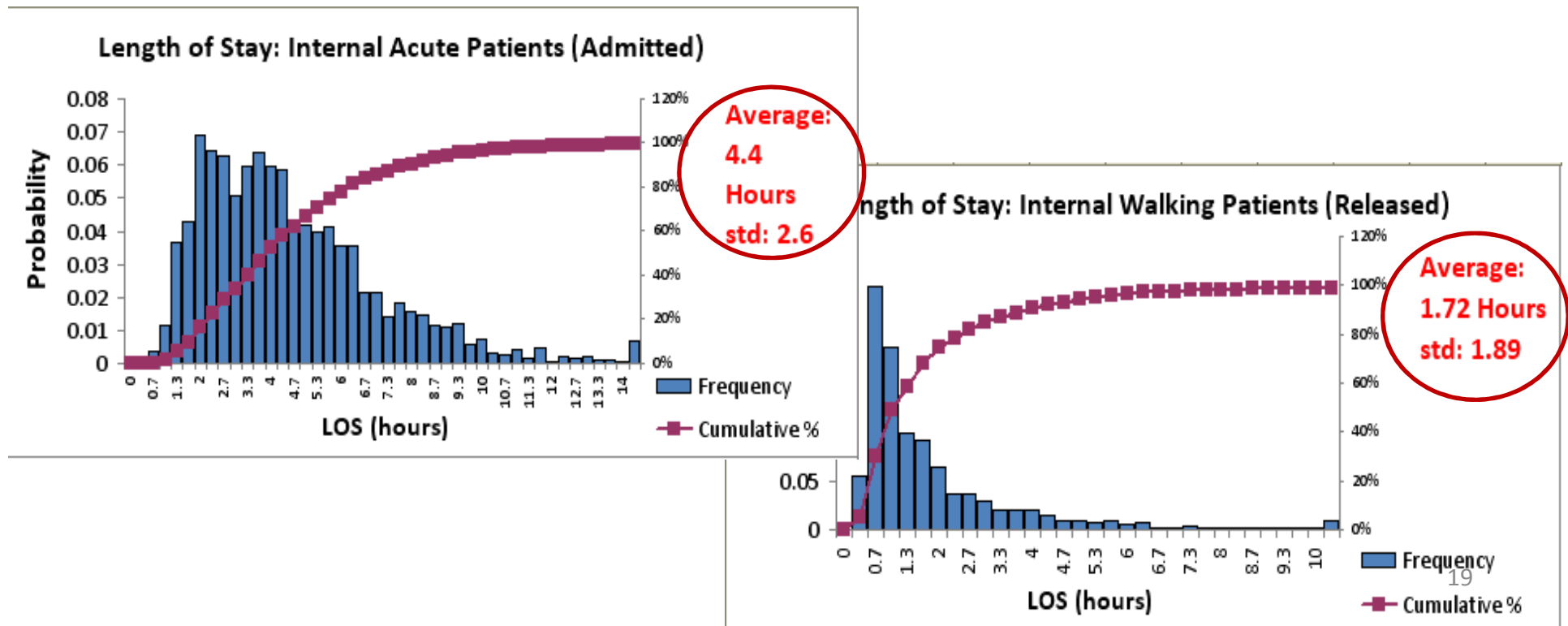


Operation	Queue Time (min.)	Service Time (min.)	Clinical Treatment Time (min.)	Number of Visits
DR	21.09	4.54		34462
Nurse	19.05	3.96		22315
CT	0.1	4.82	26.07	498
X-ray	19.53	6.42	26.19	8322
Ultrasound	1	6.09	29.03	498
Lab=Blood			61.33	4303
Admission	0.06	0.5		10099
Consulting	65.77	6.43		1216
Overall				81713
Sync	20.72			18346

Operation	Prob(Wait)
CT	0.021
LAB	0.076
X-ray	0.608
Ultrasound	0.026
Nurse	0.163
Dr	0.036
Consulting	0.069

Q3. Can we do better? (What-If)

- Focus on improving the service quality in the ED
 - Reducing the **LOS** and the **time before doctor** at the ED
- Scenario 1: **Unlimited Resources**
 - Upper bound on the performance measures
 - Change in LOS (via Simulation):



Q3. Can we do better? (What-If)

- Scenario 2: **Increase Staffing** at Rush-Hours using Square-Root Rule
 - Weekdays

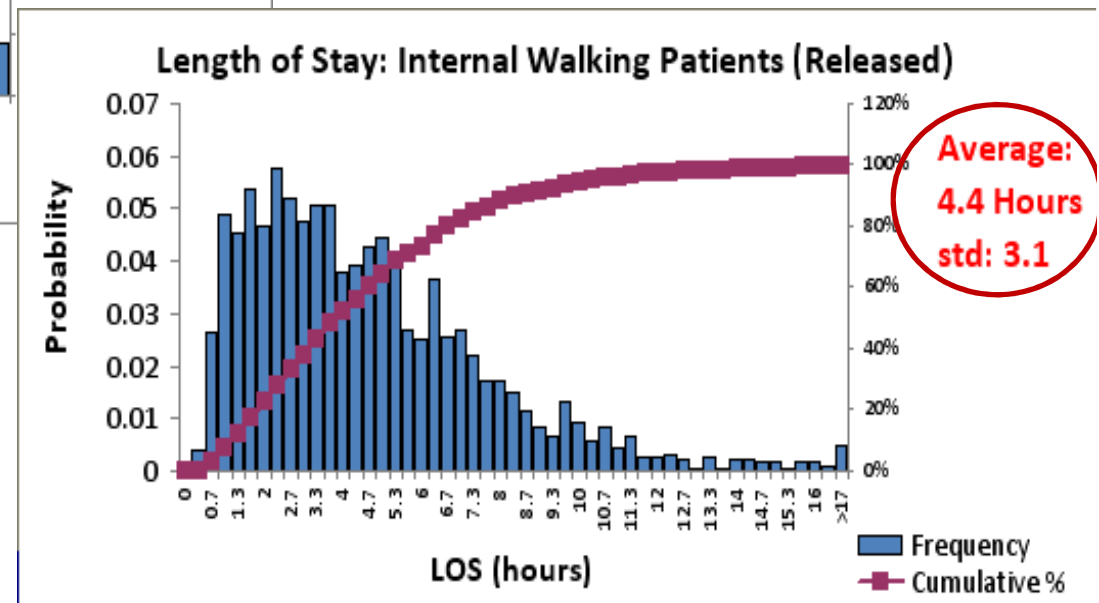
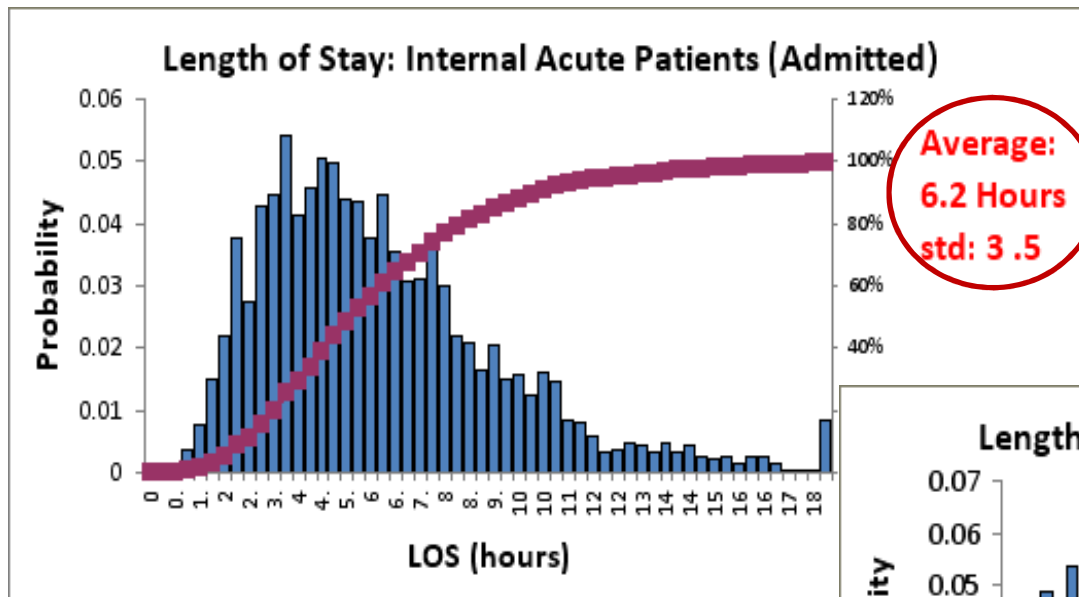
Time	Internal DR Acute	Internal DR Walking	Surgical DR	Orthopedic DR	Internal Nurse Acute	Internal Nurse Walking	Surgical Nurse
0:00	1	3	1	1	1	2	1
1:00	1	3	1	1	1	2	1
2:00	1	3	1	1	1	2	1
3:00	1	3	1	1	1	2	1
4:00	1	3	1	1	1	2	1
5:00	1	2	1	1	1	1	1
6:00	1	2	1	1	1	1	1
7:00	1	2	1	1	1	1	1
8:00	1	2	1	1	1	1	1
9:00	1	2	1	1	1	1	2
10:00	1	2	1	1	1	1	2
11:00	1	2	1	2	1	1	3
12:00	1	2	1	2	1	2	3
13:00	1	2	1	2	1	2	2
14:00	1	3	1	2	2	2	2
15:00	1	3	1	2	2	2	2
16:00	1	3	1	2	2	2	2
17:00	1	3	1	2	2	2	2
18:00	1	3	1	2	2	2	2
19:00	1	3	1	2	1	2	2
20:00	1	3	1	2	1	2	2
21:00	1	3	1	2	1	2	2
22:00	1	3	1	2	1	2	2
23:00	1	3	1	2	1	2	2

Difference from current staffing:

0	+7	0	+5	+5	-7	+1
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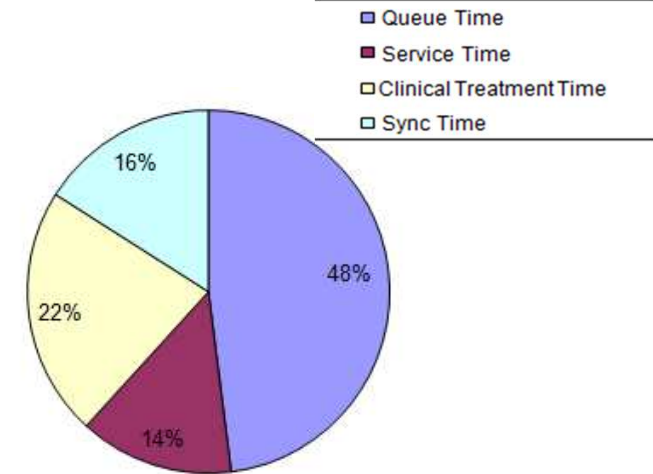
Q3. Can we do better? (What-If)

- Scenario 2: **Increase Staffing** at Rush-Hours using Square-Root Rule
 - Change in LOS (via Simulation):



Q3. Can we do better? (What-If)

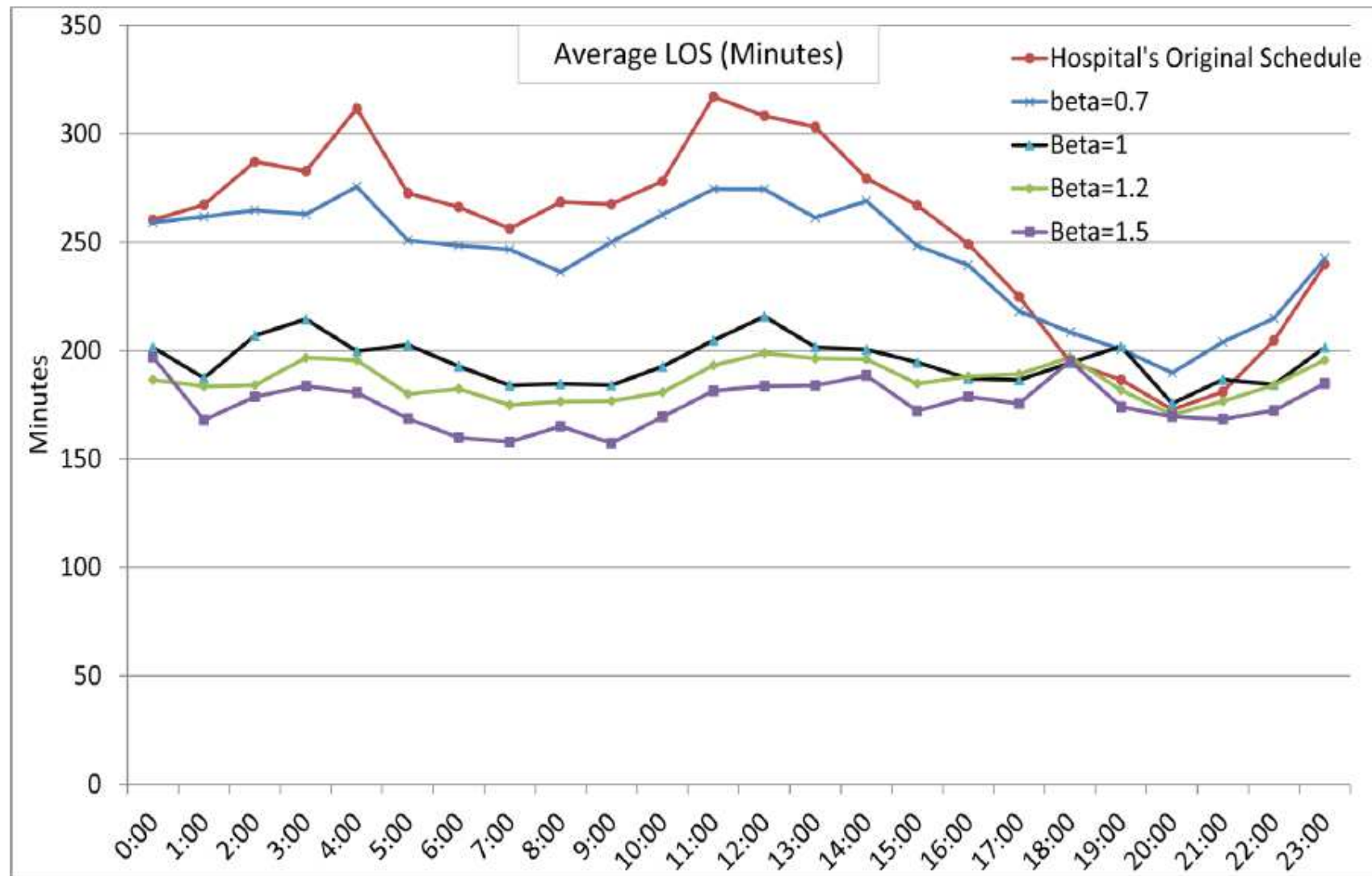
- Queue time: down from 54% to 48%.
- Service time: up from 15% to 16%.
- Clinical treatment time: up from 19% to 22%.
- Sync time: up from 12% to 24%. (the actual time spent at sync queues is down from 20.72 min to 19.73 min)



Operation	Queue Time (min.)	Service Time (min.)	Clinical Treatment Time (min.)	Number of Visits
DR	14.6	4.5	0	34477
Nurse	15.3	3.9	0	22319
CT	0.04	4.13	25.64	498
X-ray	19.22	6.56	25.9	8205
Ultrasound	1.05	5.78	27.5	498
Lab=Blood			61.93	4277
Admission	0.08	0.5		10055
Consulting	63.8	6.32		1251
Overall				81580
Sync	19.73			18190

Operation	Prob(Wait)
CT	0.02
LAB	0.076
X-ray	0.607
Ultrasound	0.027
Nurse	0.165
Dr	0.03
Consulting	0.075

Q3. Can we do better? (What-If)



Summary

- Resources are the problem
 - Lack of Internal Medicine staff
- The current staffing is not divided right over the day
- A small **increase** (decrease) in staffing causes a substantial **decrease** (increase) in the average LOS
- Staffing according to the Square-Root Rule relieves the problem of over/under staffing