Inpatient Flow Management in a Singaporean Hospital

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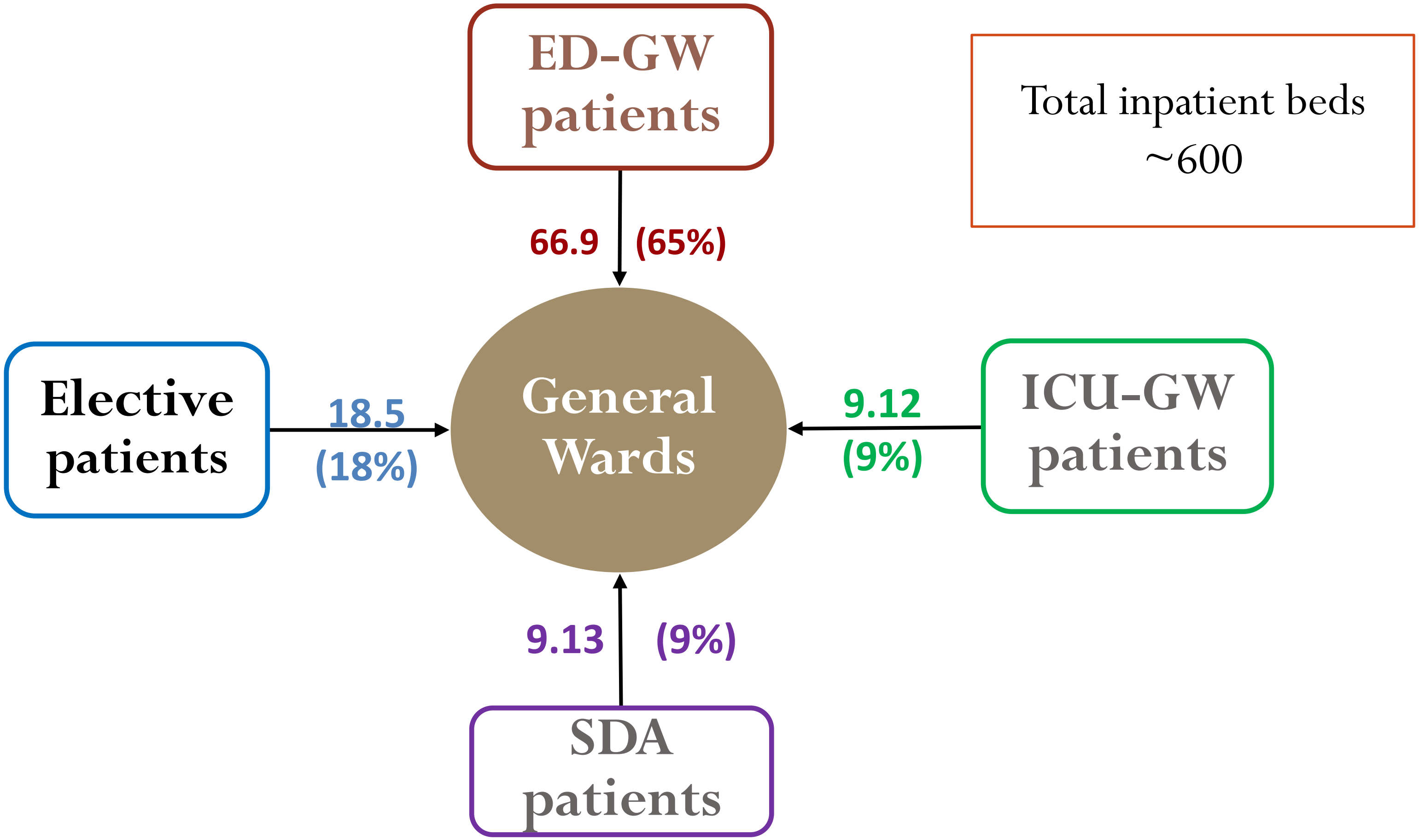
Overview

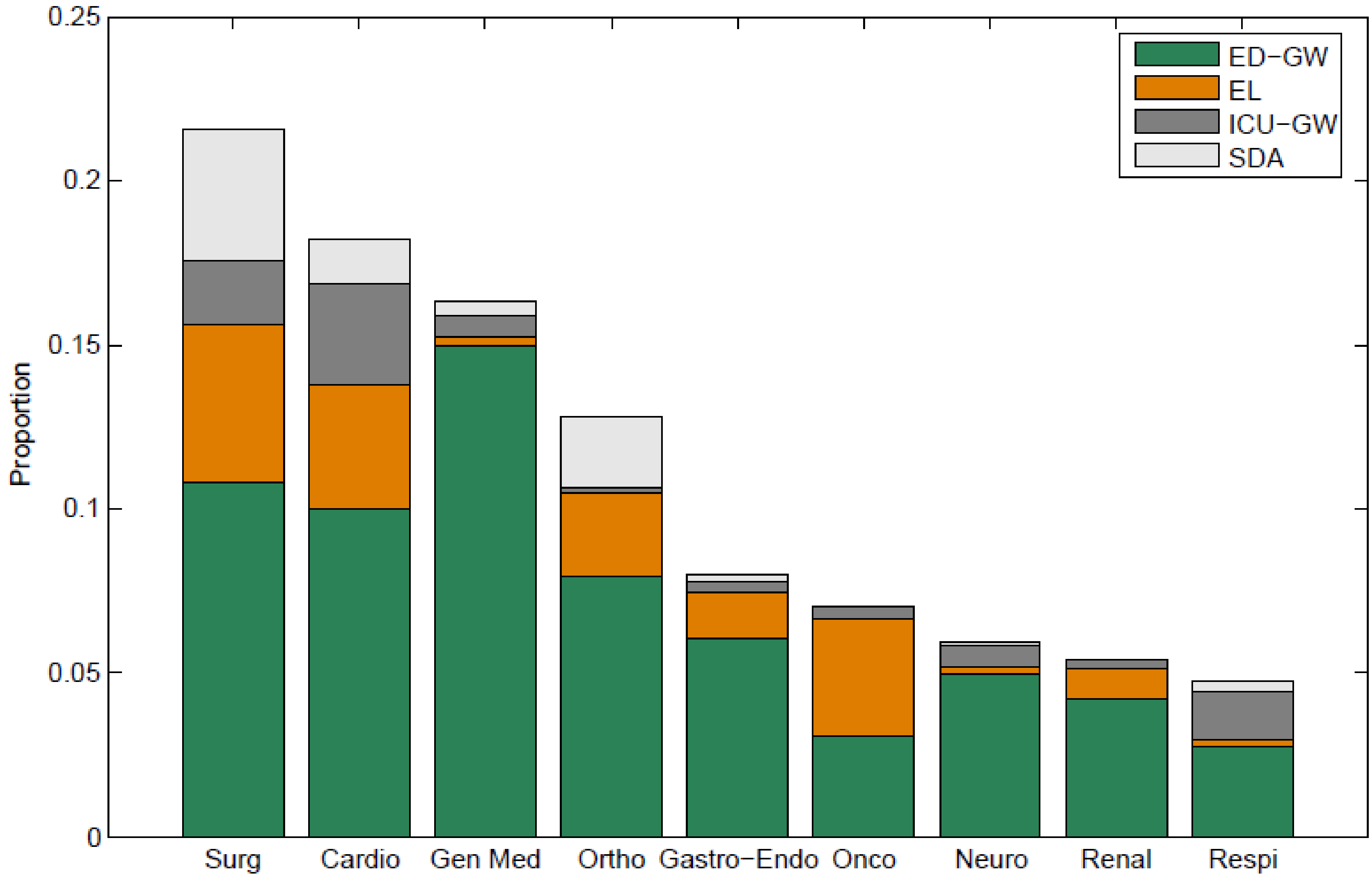
- Empirical study
  - Inpatient flow management
  - Performance comparison after an *early discharge* policy
    - Waiting time for admission to ward
    - Stabilize hourly waiting time performance
- A stochastic network model
  - Allocation delays
  - Overflow policy
  - Endogenous service times
- What-if analysis
  - Factors help to stabilize waiting time

Capacity and source of admission

- Patients from 4 admission sources competing for inpatient beds



Patient distribution



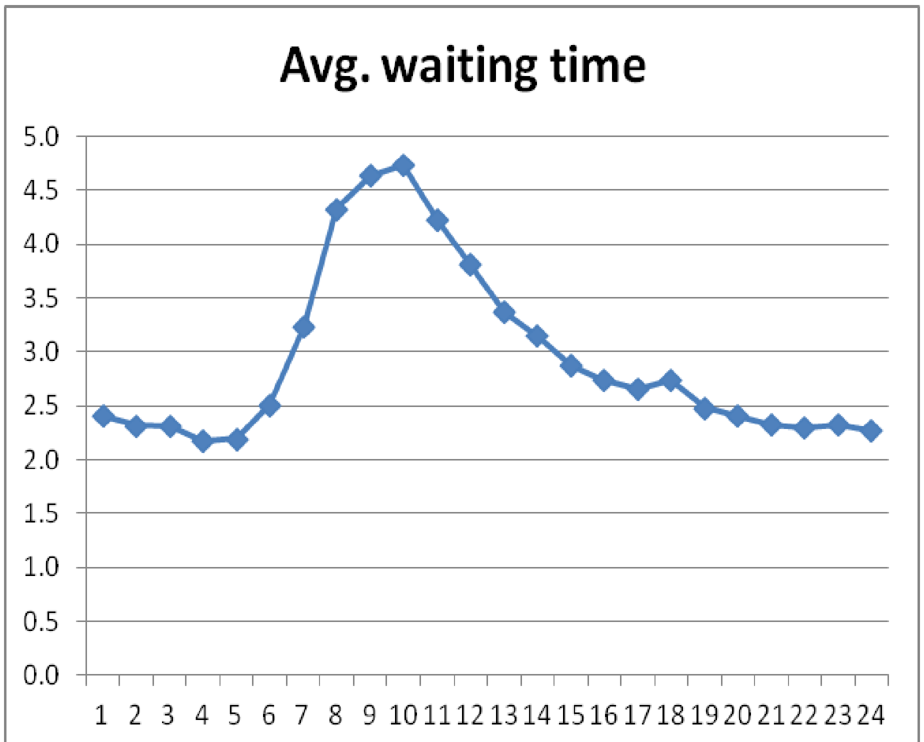
Key performance measures

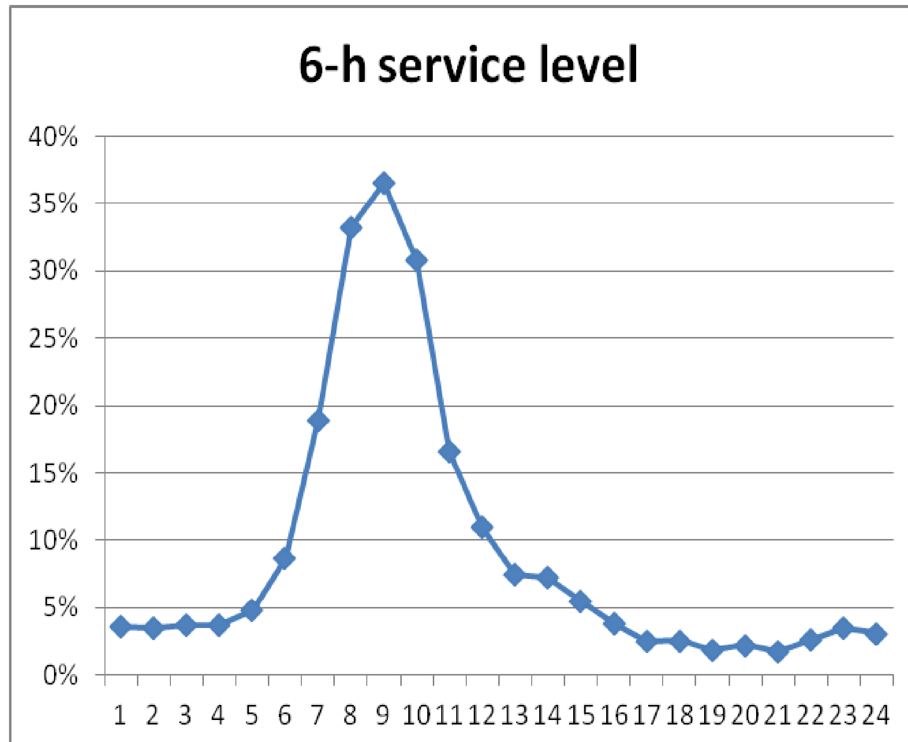
- Waiting time for admission to ward (Jan 08 – Jun 09)
  - Waiting time = admission time – bed request time
  - Average: **2.82** hour
  - **6.52**% of ED-GW patients wait more than 6 hours to get a bed

- "x-hour service level": Fraction of ED-GW patients waiting more than x hours
  - Ministry of Health (MOH) monitors 10-hour service level (**0.80%**)
  - Hospital managers also care about the 6-hour service level

Time dependency

- Waiting time depends on patient's bed request time
  - Jan 08 – Jun 09
  - Can we *stabilize*?





Literature review

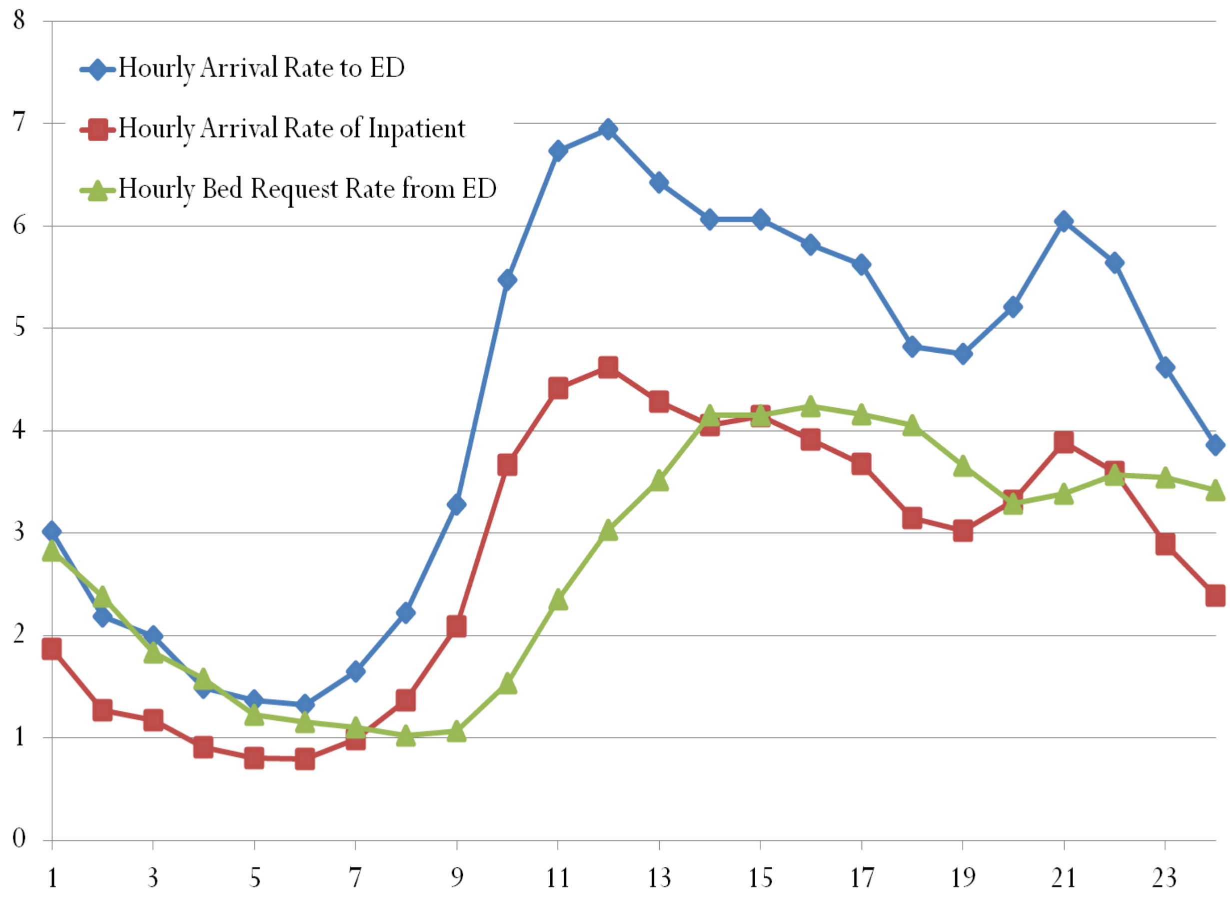
- Zohar Feldman, Avishai Mandelbaum, William A. Massey and Ward Whitt, *Management Sciences*, 2008.
  - **Staffing of Time-Varying Queues to Achieve Time-Stable Performance**

- E. S. Powell, R. K. Khare, A. K. Venkatesh, B. D. Van Roo, J. G. Adams, and G. Reinhardt, *The Journal of Emergency Medicine*, 2012
  - **The relationship between inpatient discharge timing and emergency department boarding**

  - Affiliations: Department of Emergency Medicine, Northwestern University; Harvard Affiliated Emergency Medicine Residency, Brigham and Women's Hospital–Massachusetts General Hospital, …

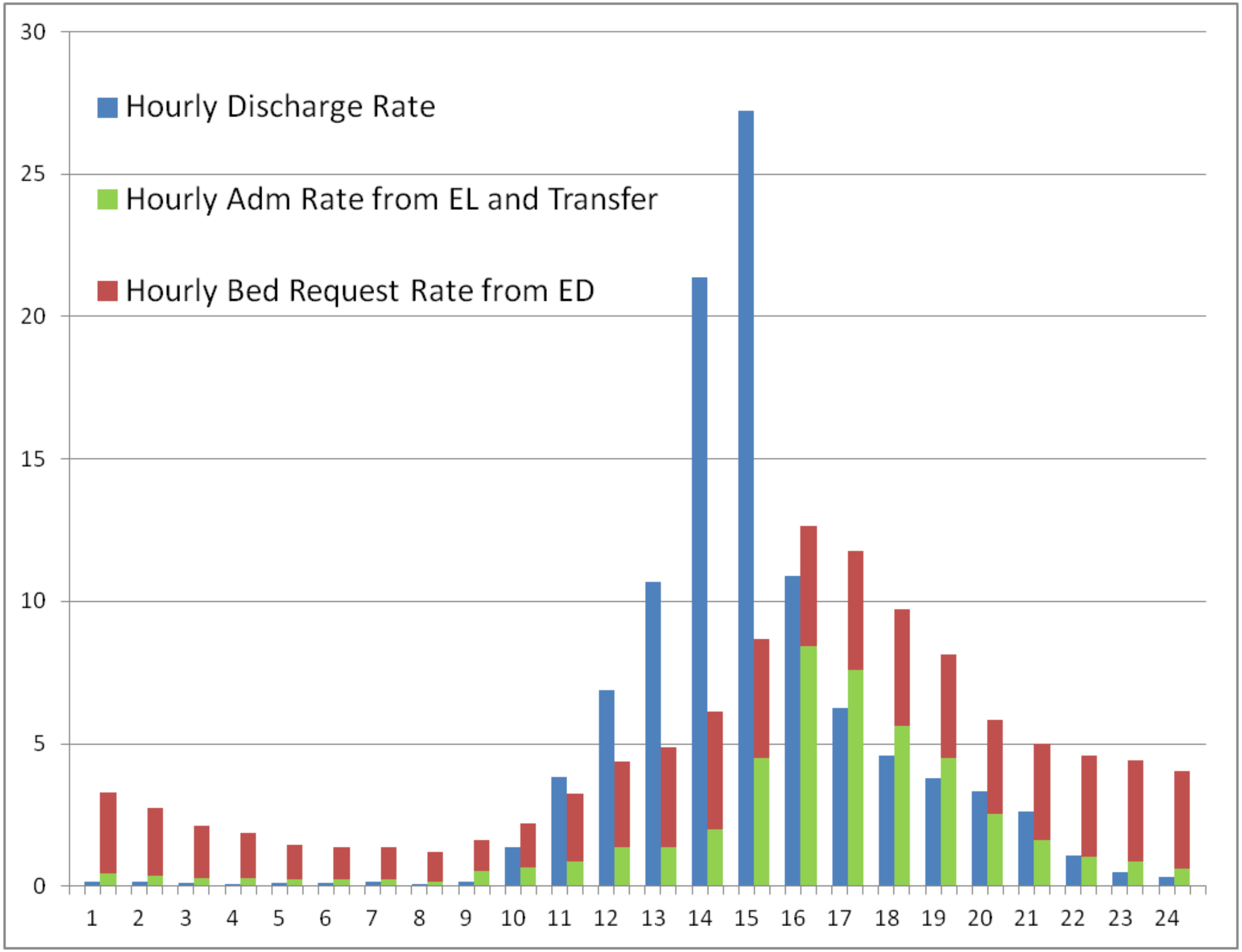
Bed request rate and arrivals to ED

- ED-GW patient's bed request rate (**green** curve) depends on arrival rate to ED (**blue** curve)



Mismatch between demand and supply of beds

- Jan 08 – Jun 09



Early discharge policy

- Moving the discharge time a few hours earlier in the day
  - Safe: limited effect in increasing patient's risk
  - Costly to implement

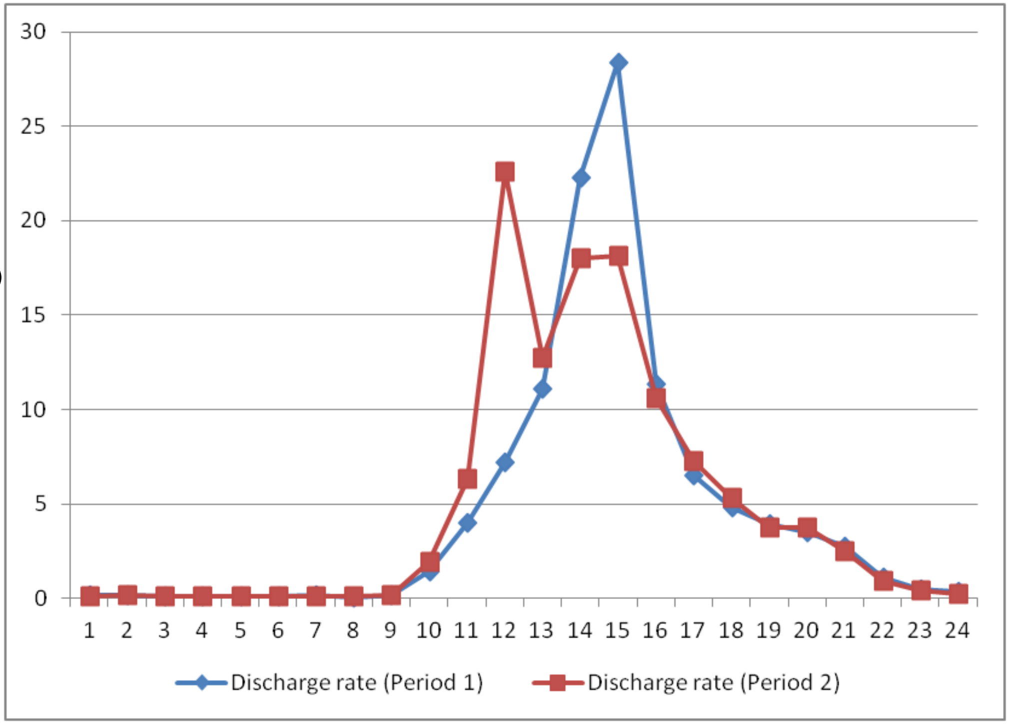
- Recommended by many studies, policy guidelines:
  - National Health Service (NHS, UK): "*planning for a reasonable proportion of patients to leave the ward before 11 am helps to manage the total loading on beds*"

  - Intuition: moving the discharge time earlier (by even 1 or 2 hours) can improve operations and patient flow.

[1] NHS. http://www.institute.nhs.uk/quality_and_service_improvement_tools/quality_and_service_improvement_tools/discharge_planning.html
[2] Achieving timely simple discharge from hospital. NHS. 2004.
[3] Discharge Planning Handbook for Healthcare: Top 10 Secrets to Unlocking a New Revenue Pipeline. 2008. Productivity Press.
[4] Discharge by Appointment: Freeing Up In-Patient Bed Capacity.

Data

- The hospital implemented early discharge policy since July 2009
- Study two periods of data
  - Jan 2008 to Jun 2009 (Period 1)
    - **13**% before noon
  - Jan 2010 to Dec 2010 (Period 2)
    - **26**% before noon



- Is early discharge policy helpful?
  - Empirical analyses
  - Use model to evaluate
- Key performance measures in the two periods
  - Waiting time statistics (quality)
  - Overflow rate (cost)

Empirical Analysis on the two periods

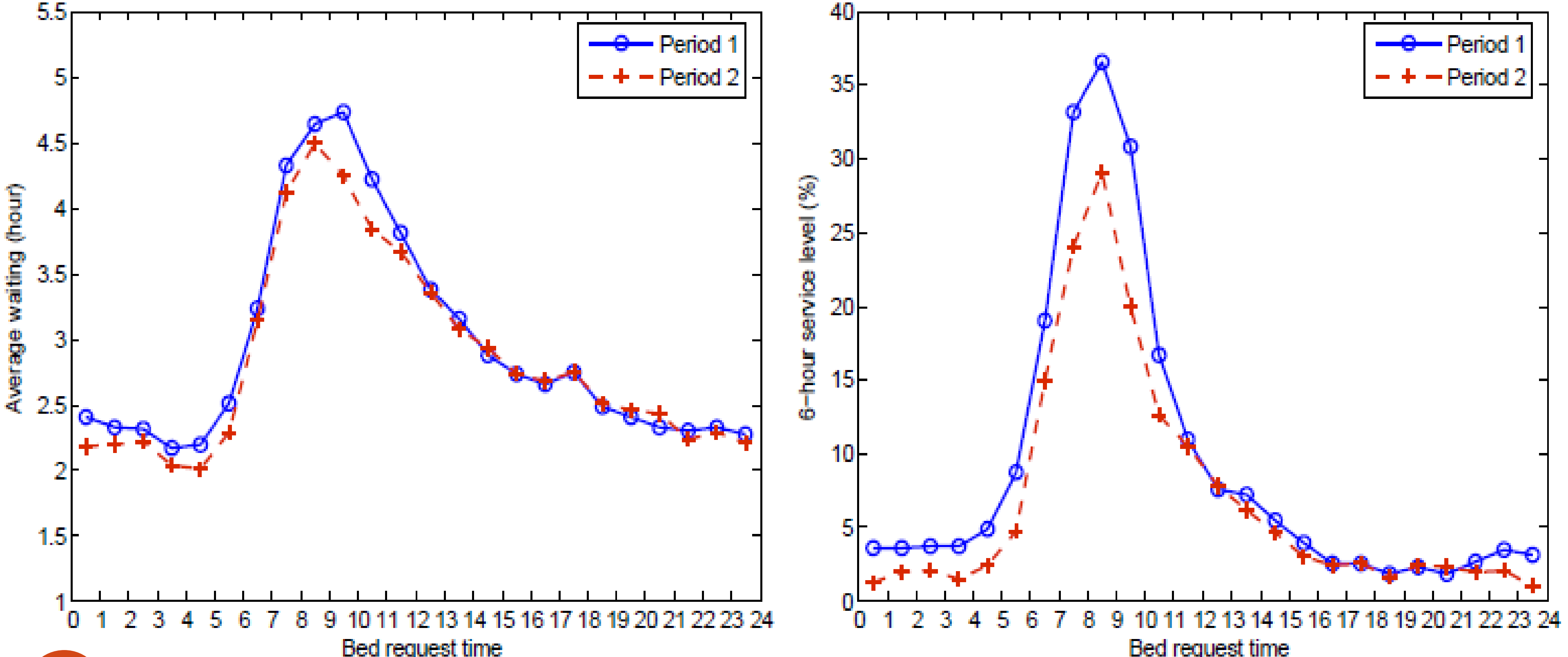
- Waiting time performance

- Overflow rate
  - Period 1: **26.9%**
  - Period 2: **25.0%**

- BOR

Waiting time for ED-GW patients

	1st period	2nd period
Average waiting time	2.82 h	2.77 h
6-hour service level	6.52%	5.13%

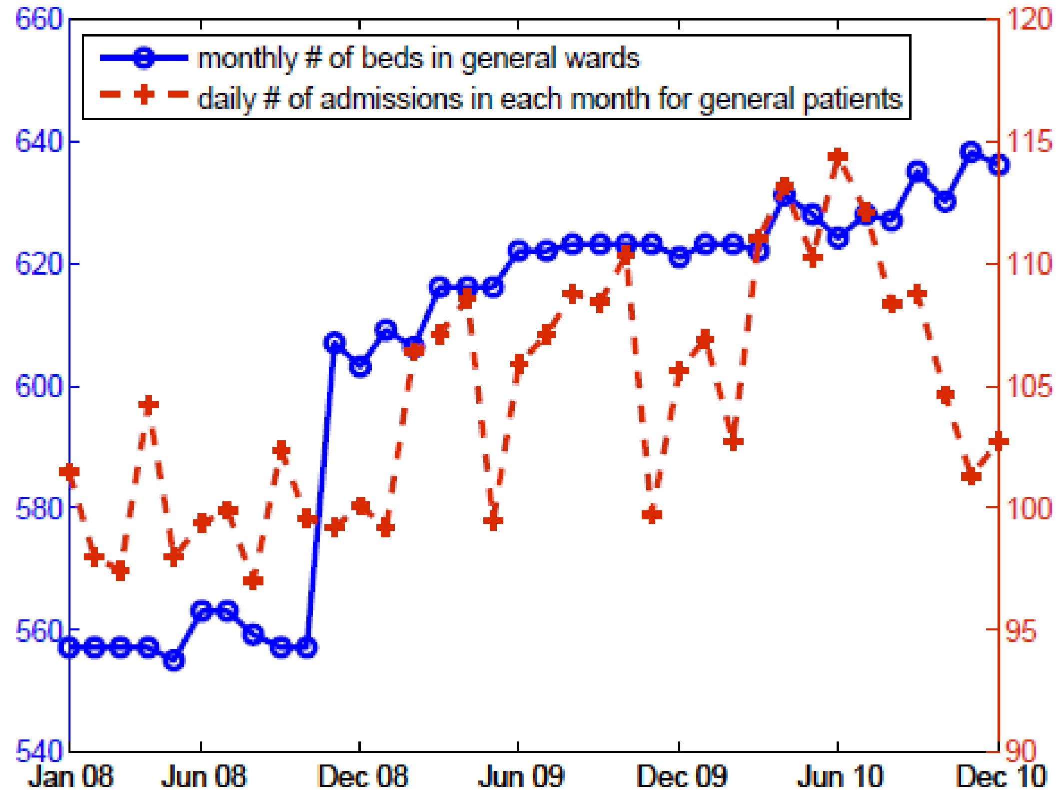


Challenges

- Does the modest improvement come from the early discharge?
- More importantly, is any operational policy that can stabilize the waiting time?

Unstable Environment

- Both arrival volume and capacity increases during 2008 to 2010
- Bed occupancy rate (BOR) reduces in the Period 2
  - Period 1: **90.3%**
  - Period 2: **87.6%**



- Need a model to help evaluate the effect of early discharge

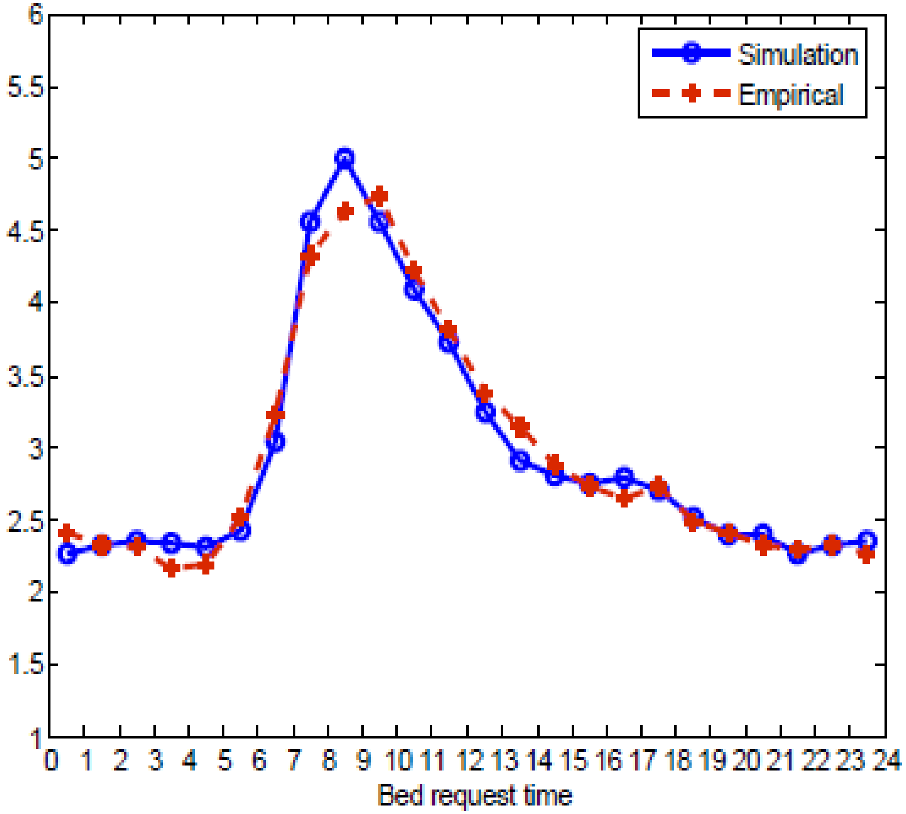
A stochastic model

- Multi-class, multi-server pool system
  - Each server pool is either dedicated to one class of customer or flexible to serve two and more classes of customers
- Periodic arrival
  - 4 types of arrival (ED-GW, Elective, ICU-GW, SDA) for each specialty
- A novel service time model
- And other key components

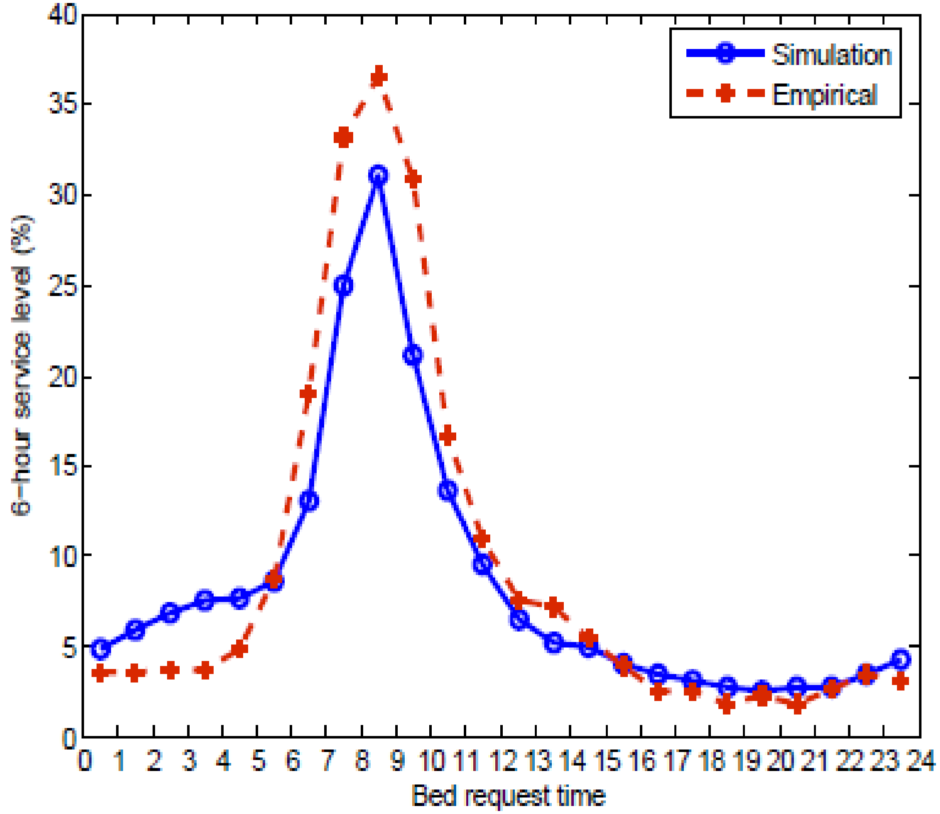
Simulation replicates most performance measures

- Hourly waiting time performances

(a) Hourly average waiting time



(b) Hourly 6-hour service level



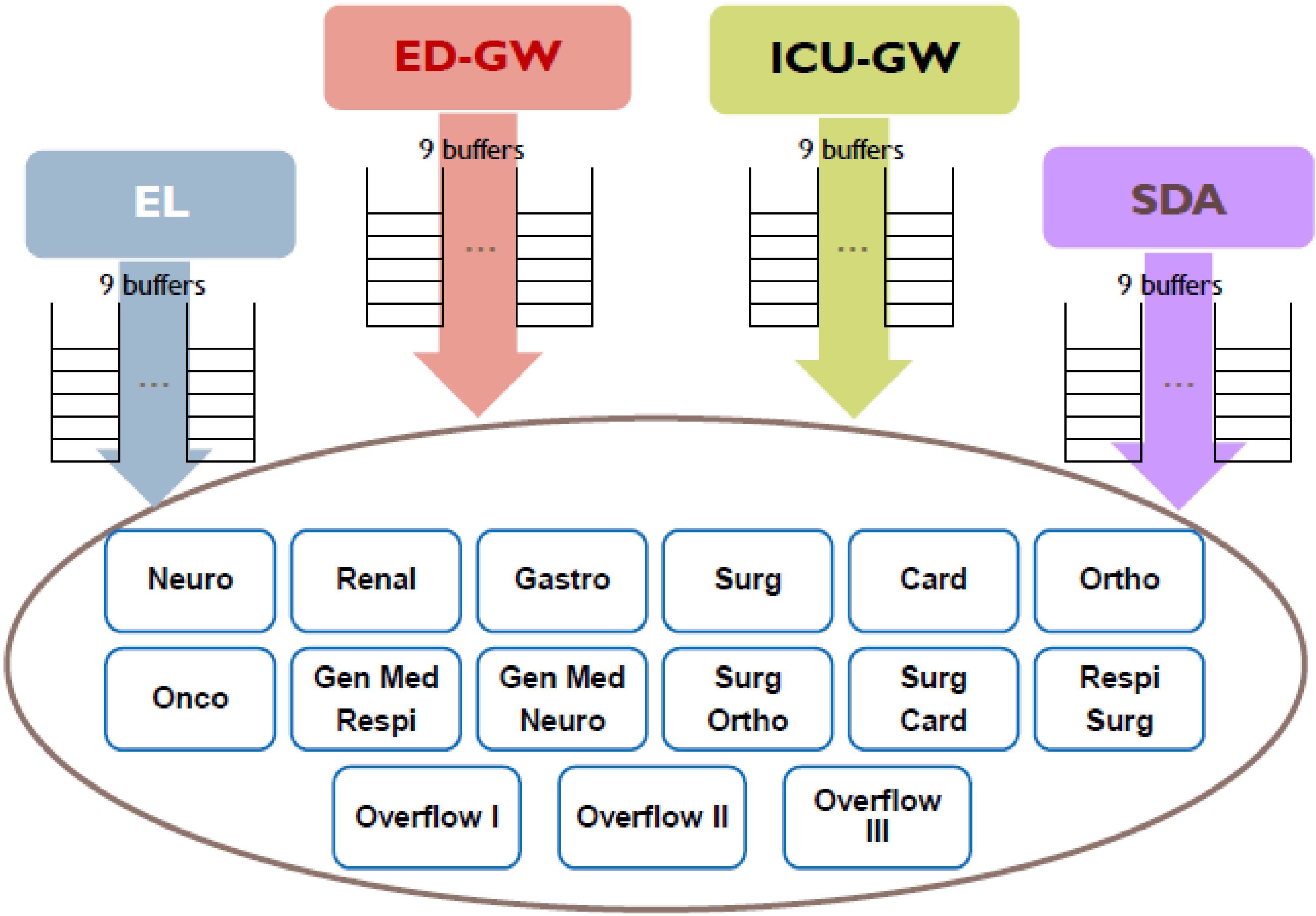
Key modeling components

- Service time model
  - Determined by admission time, **LOS** and discharge distribution
  - An endogenous modeling element
  - No longer i.i.d.

- Allocation delays
  - "Secondary" bottlenecks other than bed availability
    - Yankovic and Green (2011)
    - Armony et al (2011)

- Overflow policy
  - When to overflow a patient
  - Overflow to which server pool

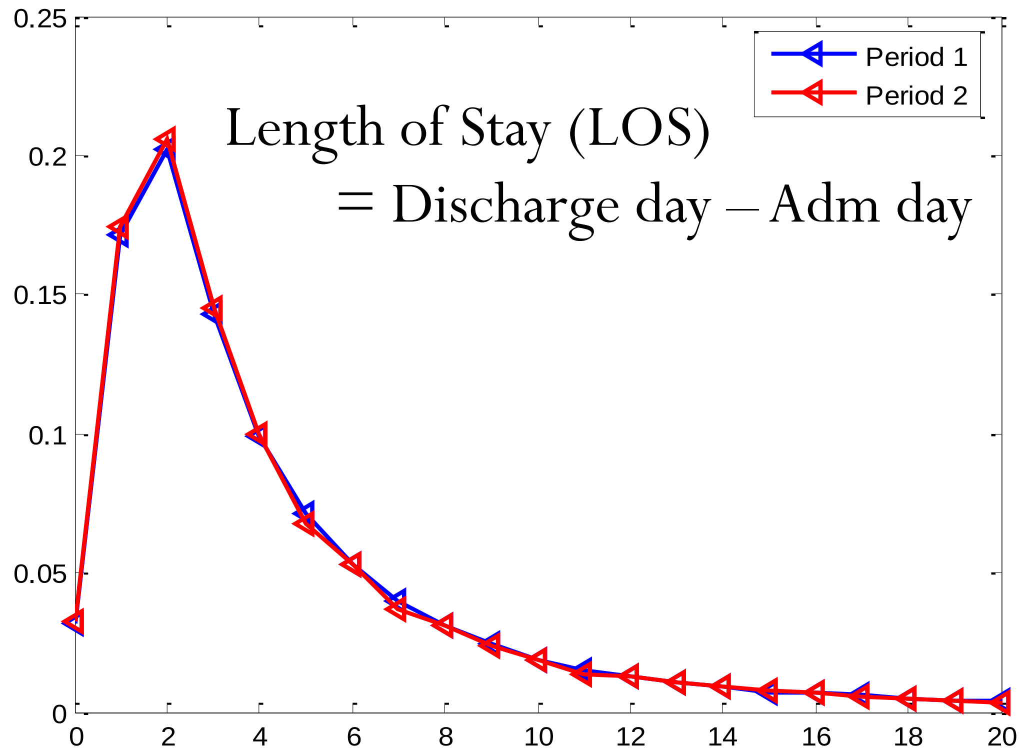
Network structure



Service time model

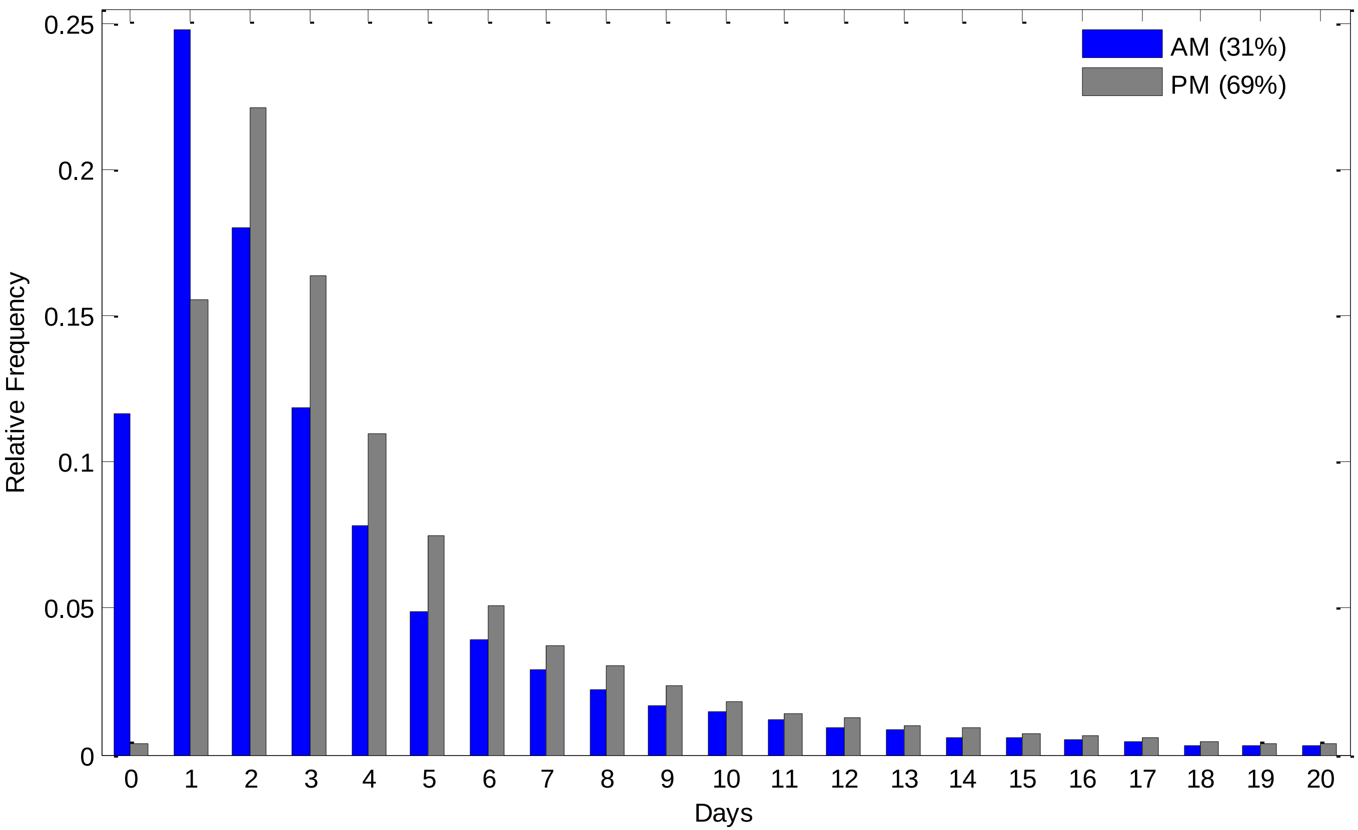
- Service time model
  - Service time = Discharge time – Admission time

    = **LOS + Dis hour – Adm hour**
- LOS distribution
  - Average is ~ 5 days
  - Depend on *admission source* and *specialty*



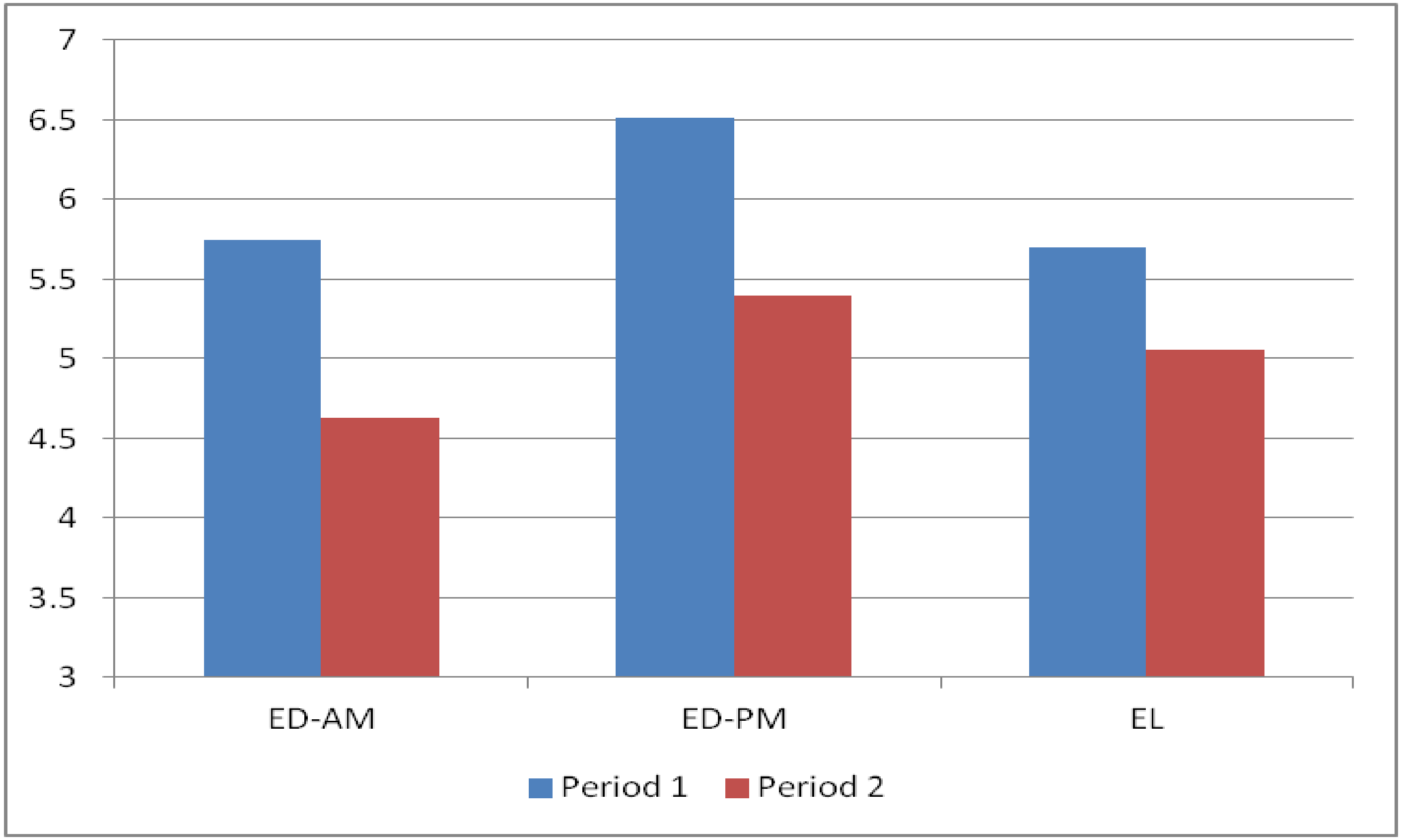
AM PM patients (ED-GW patients)

- The admission time affects LOS
  - AM patients: average LOS = 4.24 days
  - PM patients: average LOS = 5.31 days



Renal patients show a great reduction in Average LOS

- Average LOS is reduced by almost 1 day

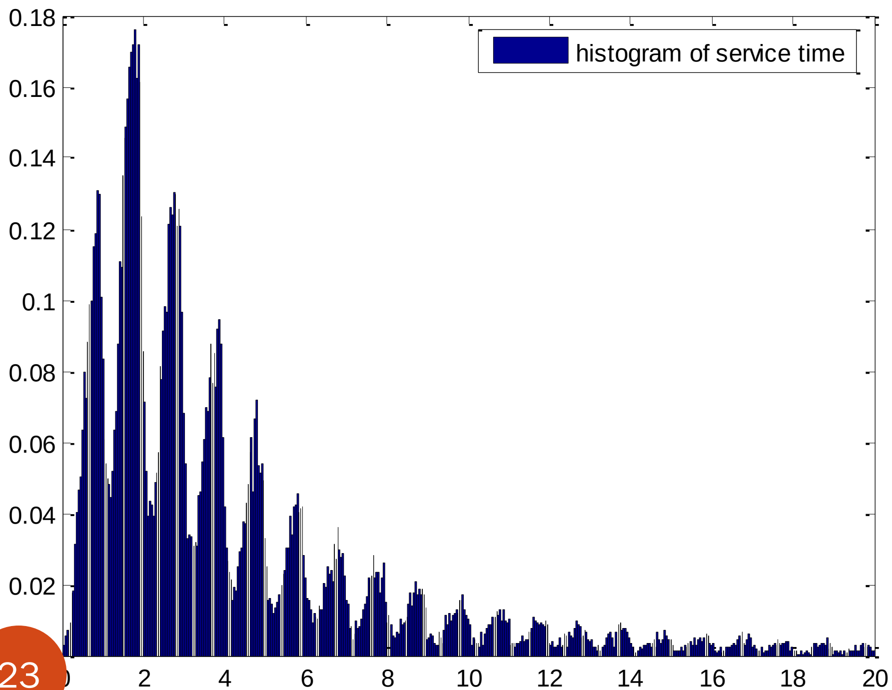


Verify the service time model

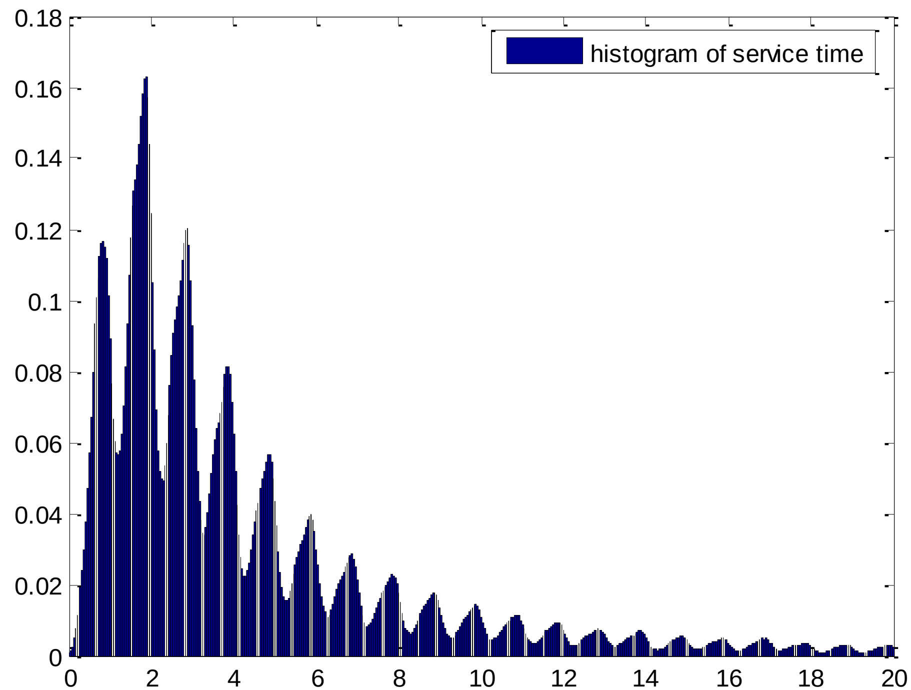
- Service time model
  - Service time = LOS + Discharge hour – Adm hour

Matching empirical

(a) Empirical



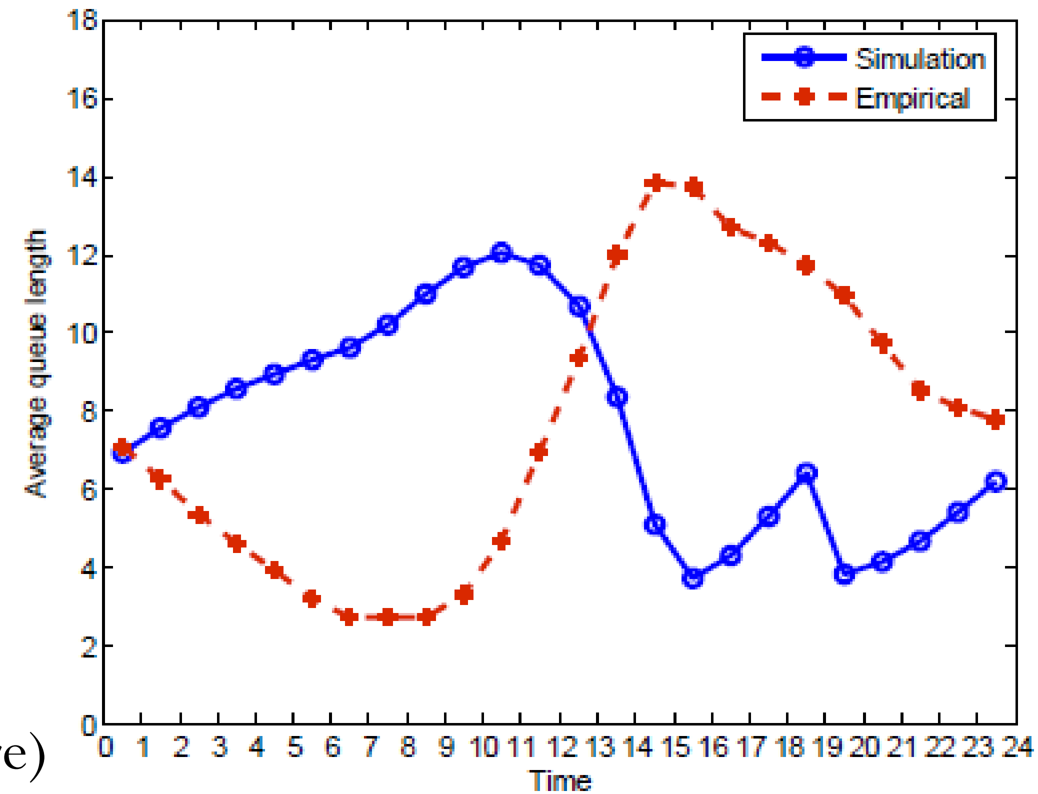
(b) Simulation output



Pre- and post-allocation delays

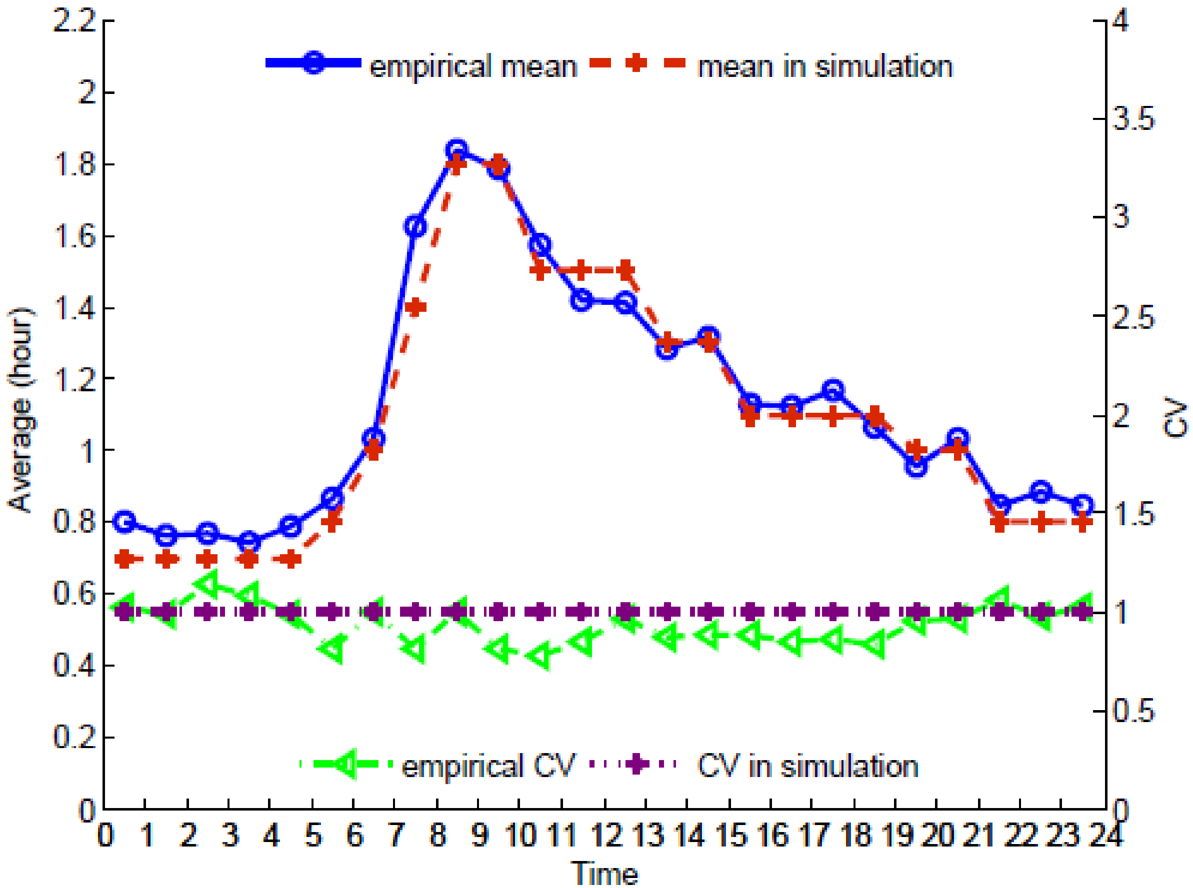
- Patient experiences additional delays upon arrival and when a bed is allocated
  - Pre-allocation delay
    - BMU search/negotiate for beds
  - Post-allocation delay
    - Delays in ED discharge
    - Delays in the transportation
    - Delays in ward admission

- Must model bed turnover component
  - If not, hourly queue length does not match (right figure)



Time-dependent allocation delays

- The mean of allocation delay depends on when it is initiated
  - Use log-normal distribution
  - Pre-allocation delay



Overflow policy

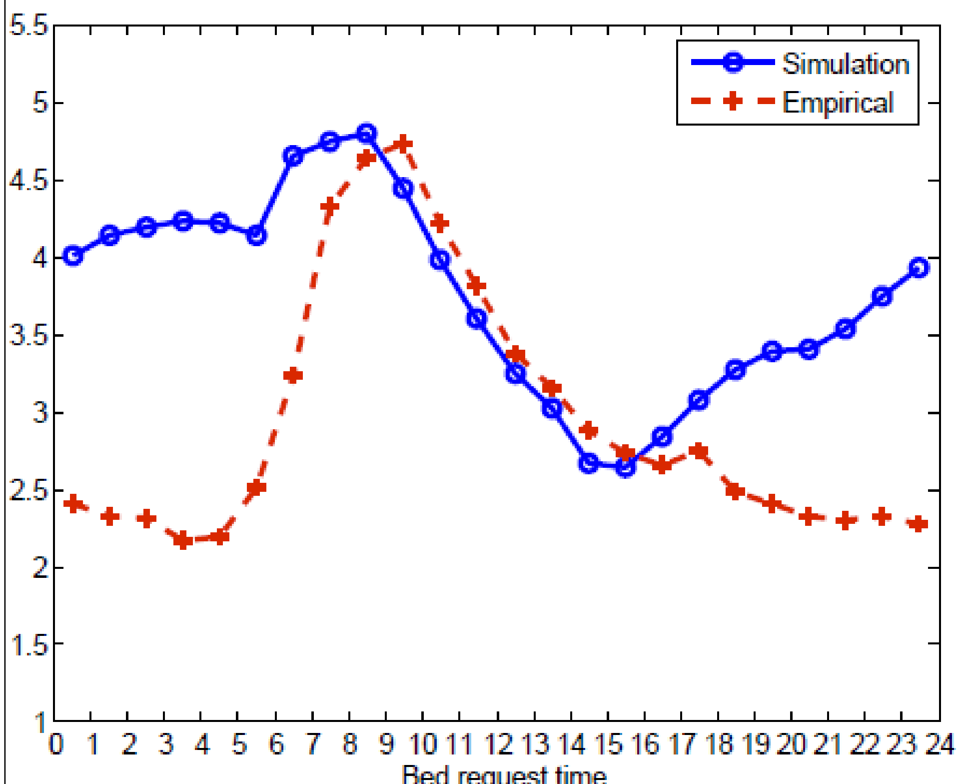
- When a patient's waiting time exceeds certain threshold, the patient can be overflowed to a "wrong" ward
  - Beds are partially flexible
  - Overflow wards have certain priority

Cluster	1st Overflow	2nd Overflow	3rd Overflow
Medicine	Other Med	Surgery/OG	Ortho
Surgery	Other Surg	Ortho /OG	Medicine
Ortho	Other Ortho	Surgery	Medicine

Dynamic overflow policy

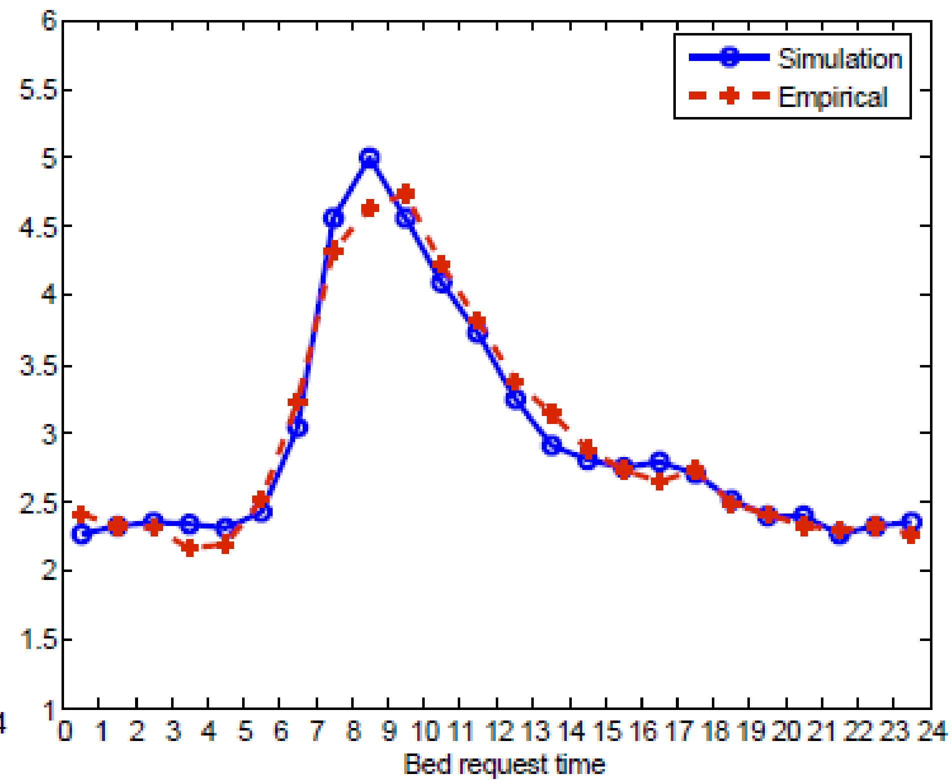
Fixed threshold

- Threshold: 4.0 h

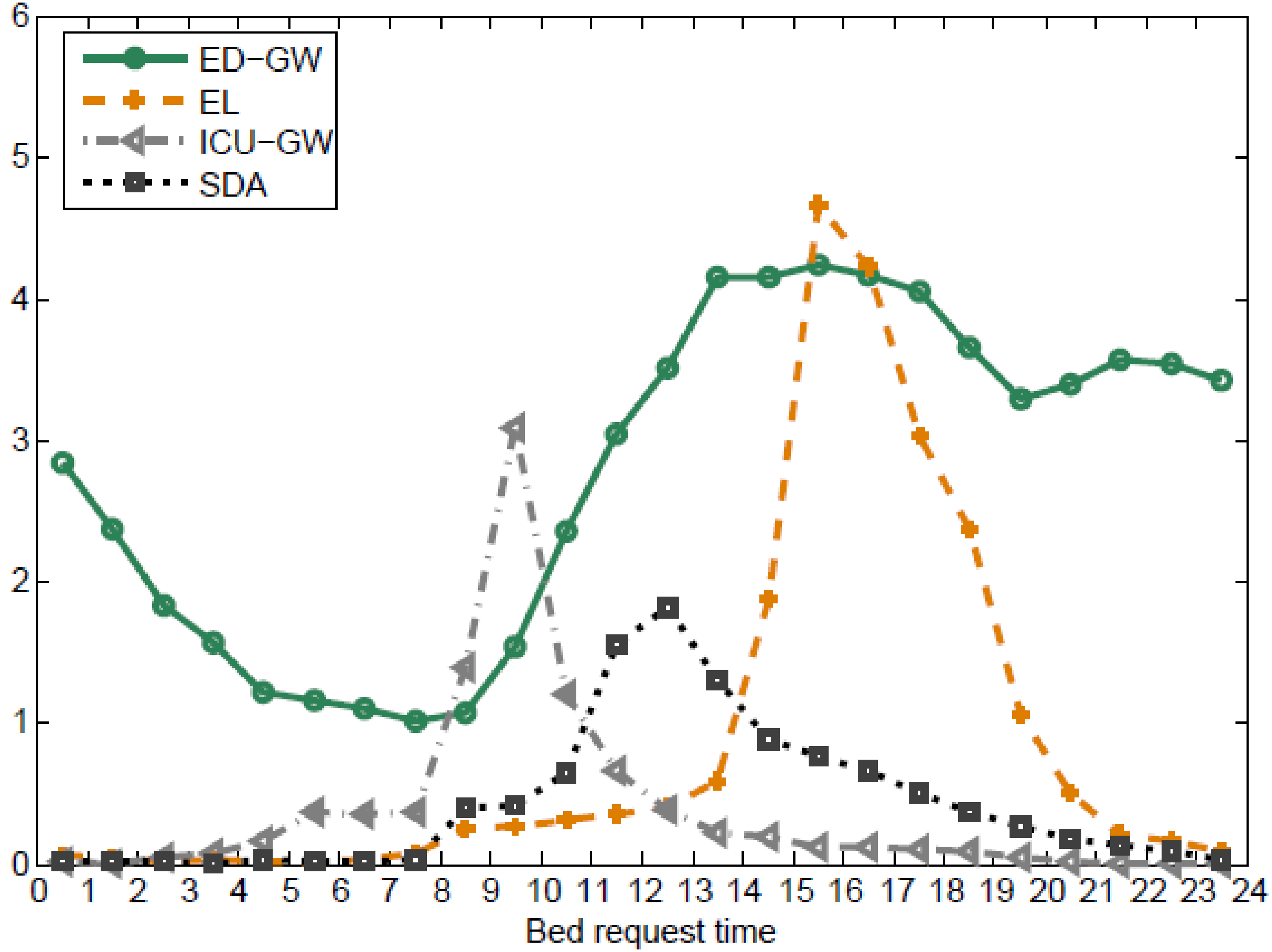


Dynamic threshold

- Threshold: 0.5 h for arrival between 7 pm and 7 am (next day); 5.0 h for others



Time-varying arrival rates



Simulation results

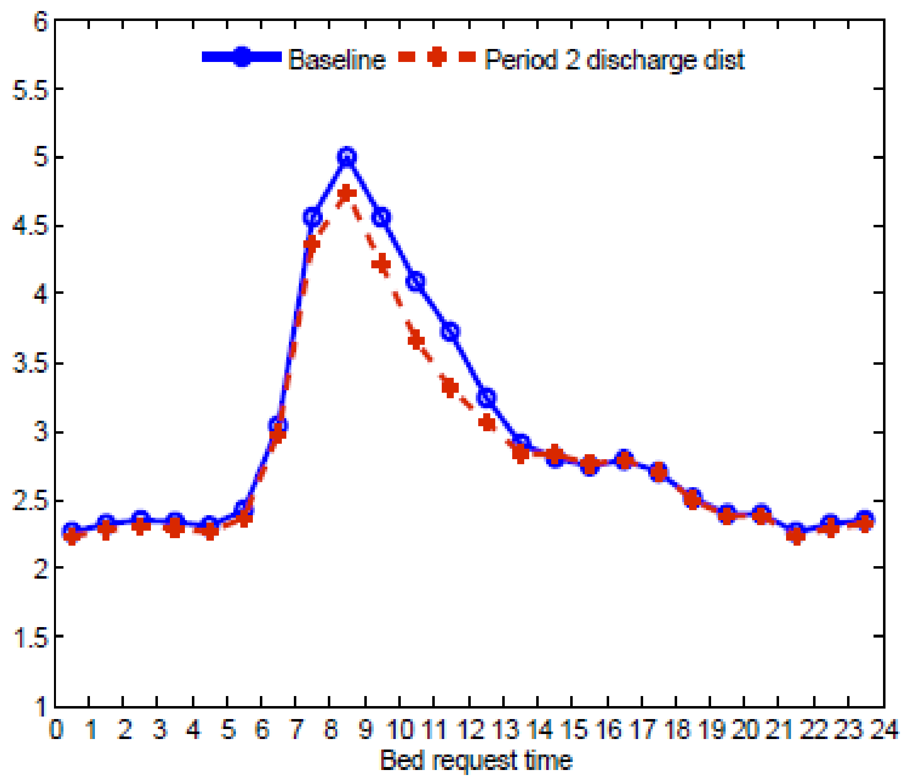
- Whether early discharge policy is beneficial or not

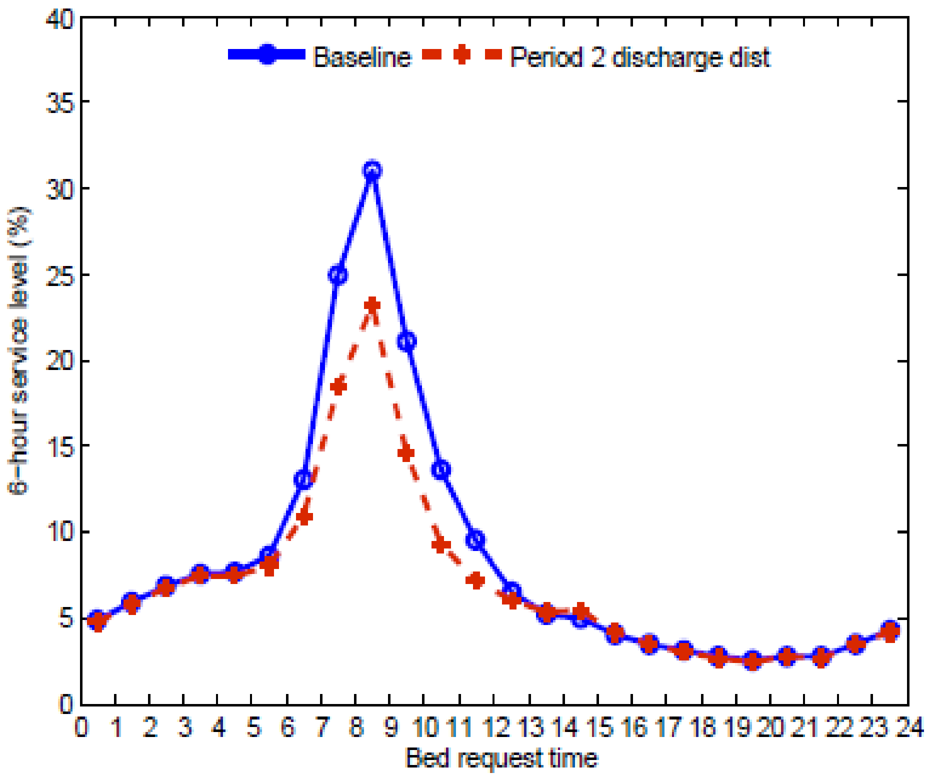
- What-if analysis

Simulation results

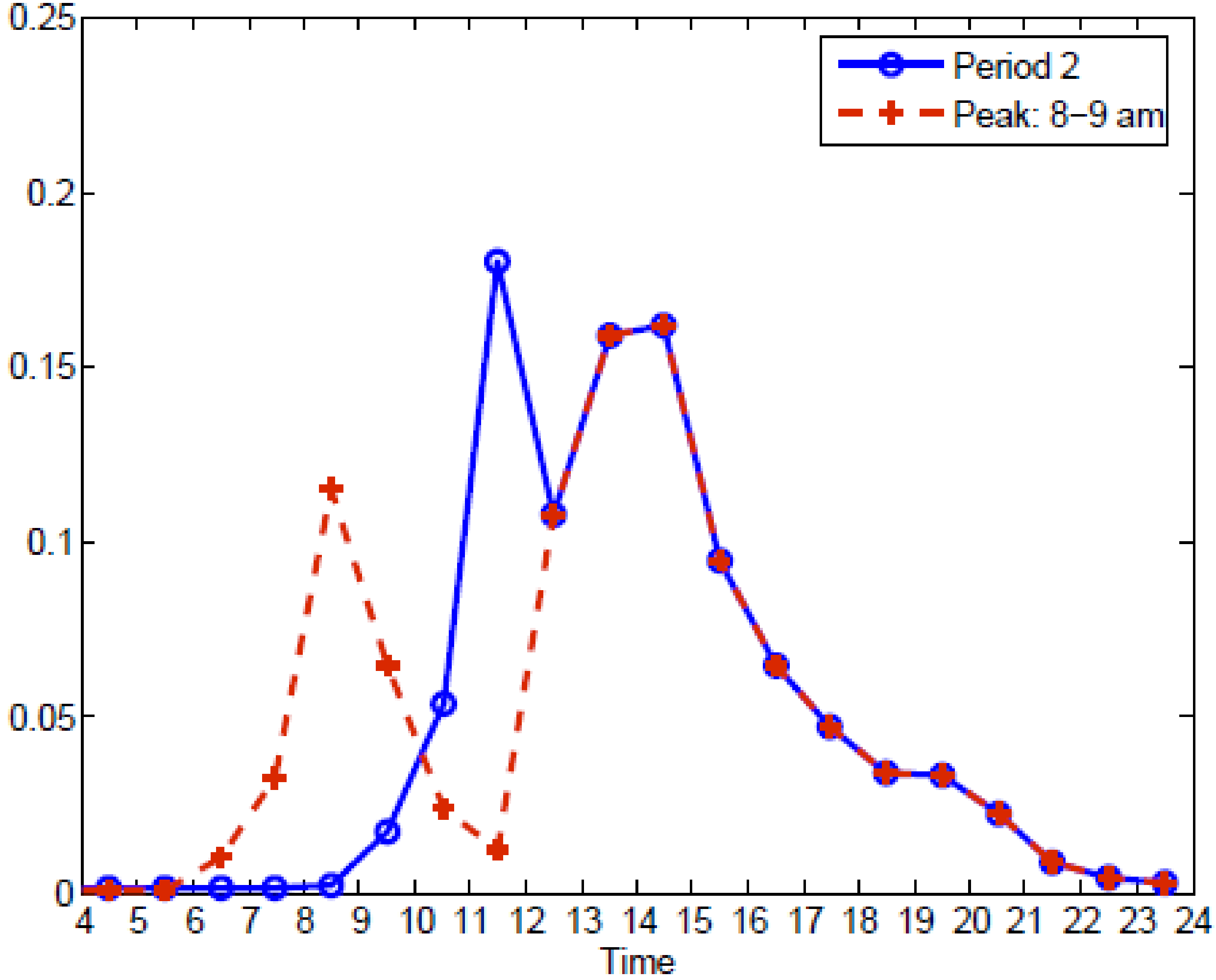
- Simulation shows the early discharge policy has little improvement

  (a) hourly avg. waiting time (b) 6-hour service level





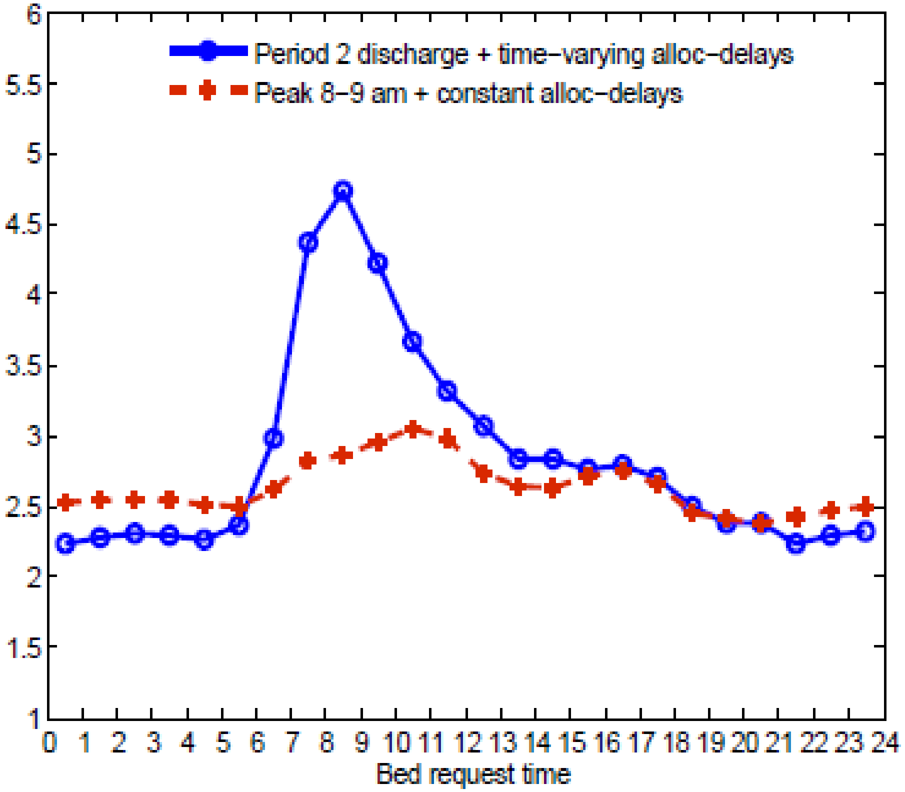
Aggressive early discharge policy



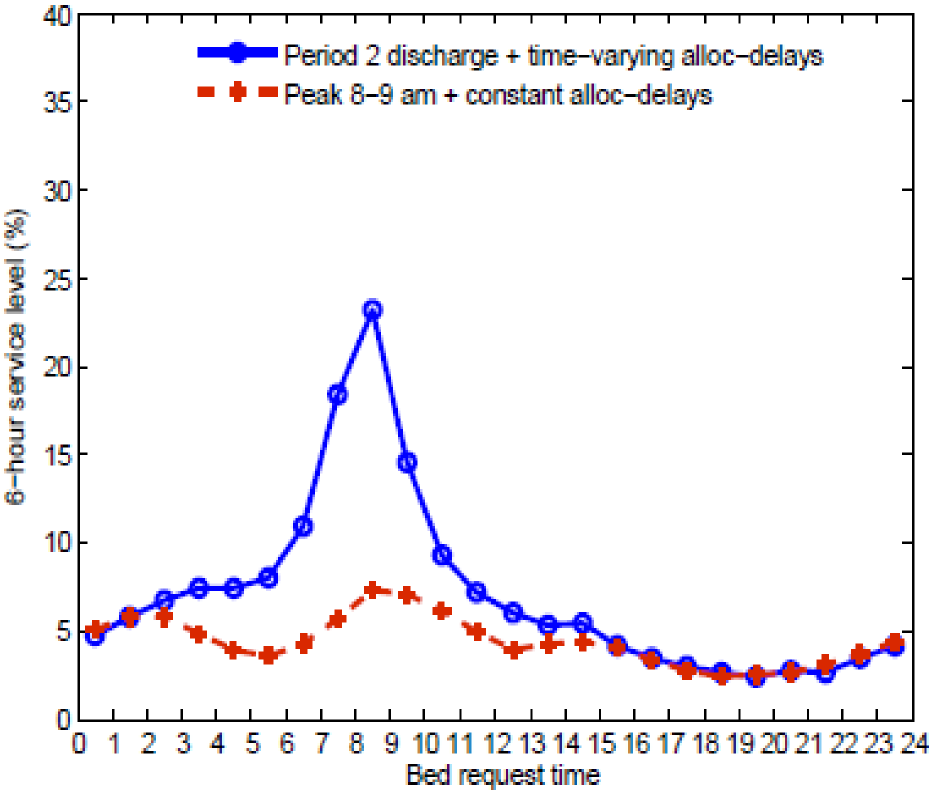
Aggressive early discharge + smooth allocation delay

- Waiting time performances can be stabilized

(a) hourly avg. waiting time



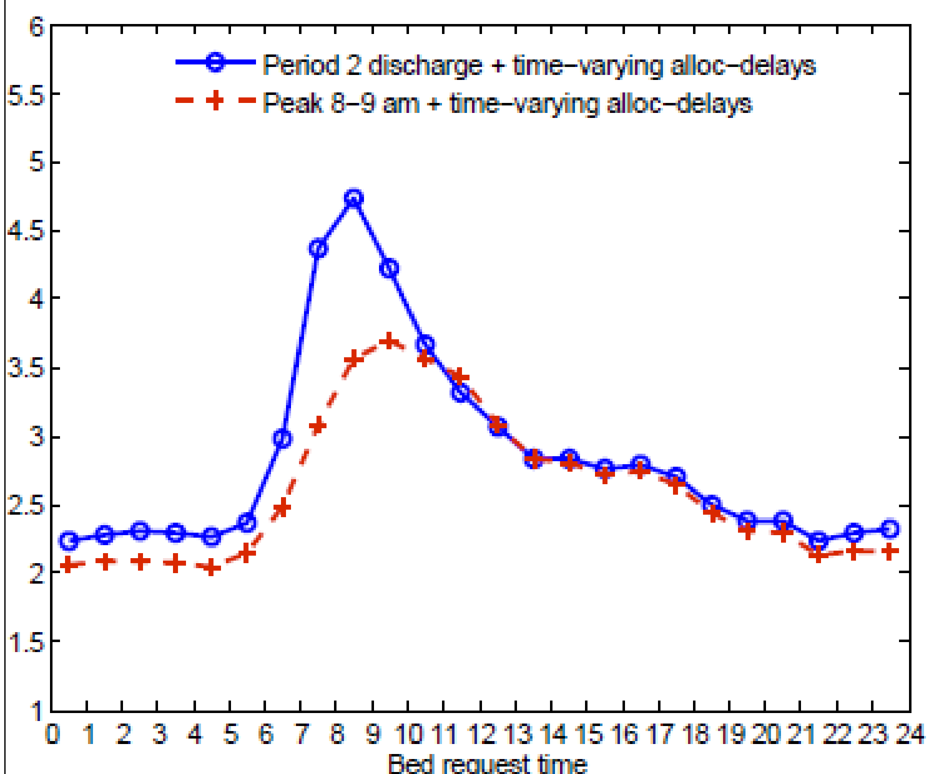
(b) 6-hour service level

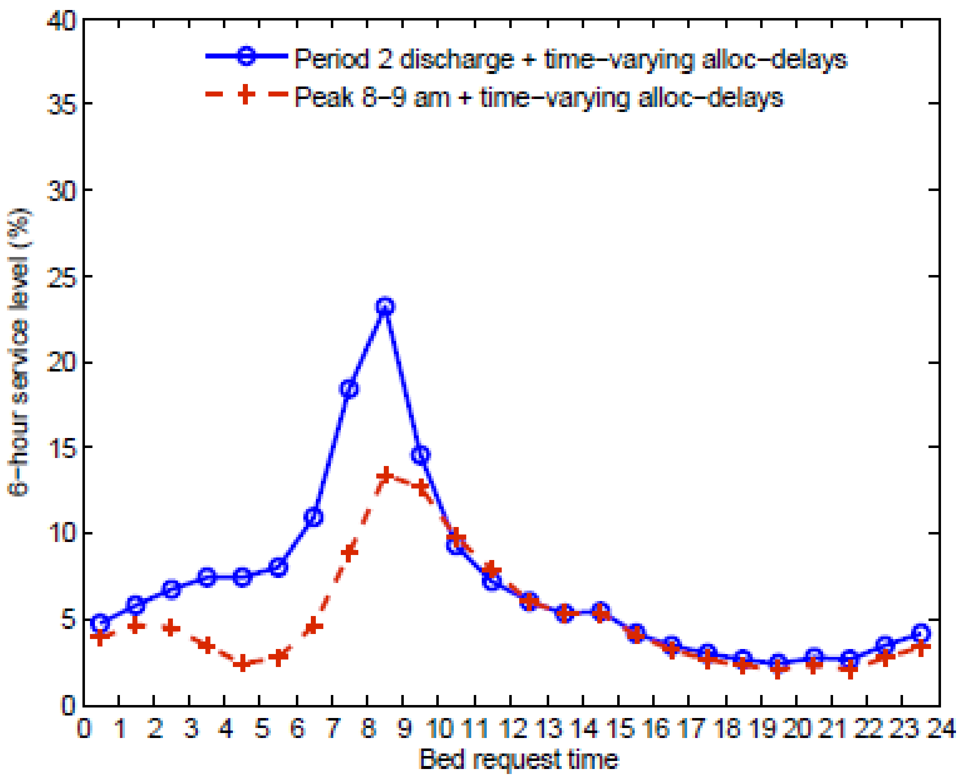


Only use aggressive early discharge

- Cannot be stabilized

(a) hourly avg. waiting time (b) 6-hour service level

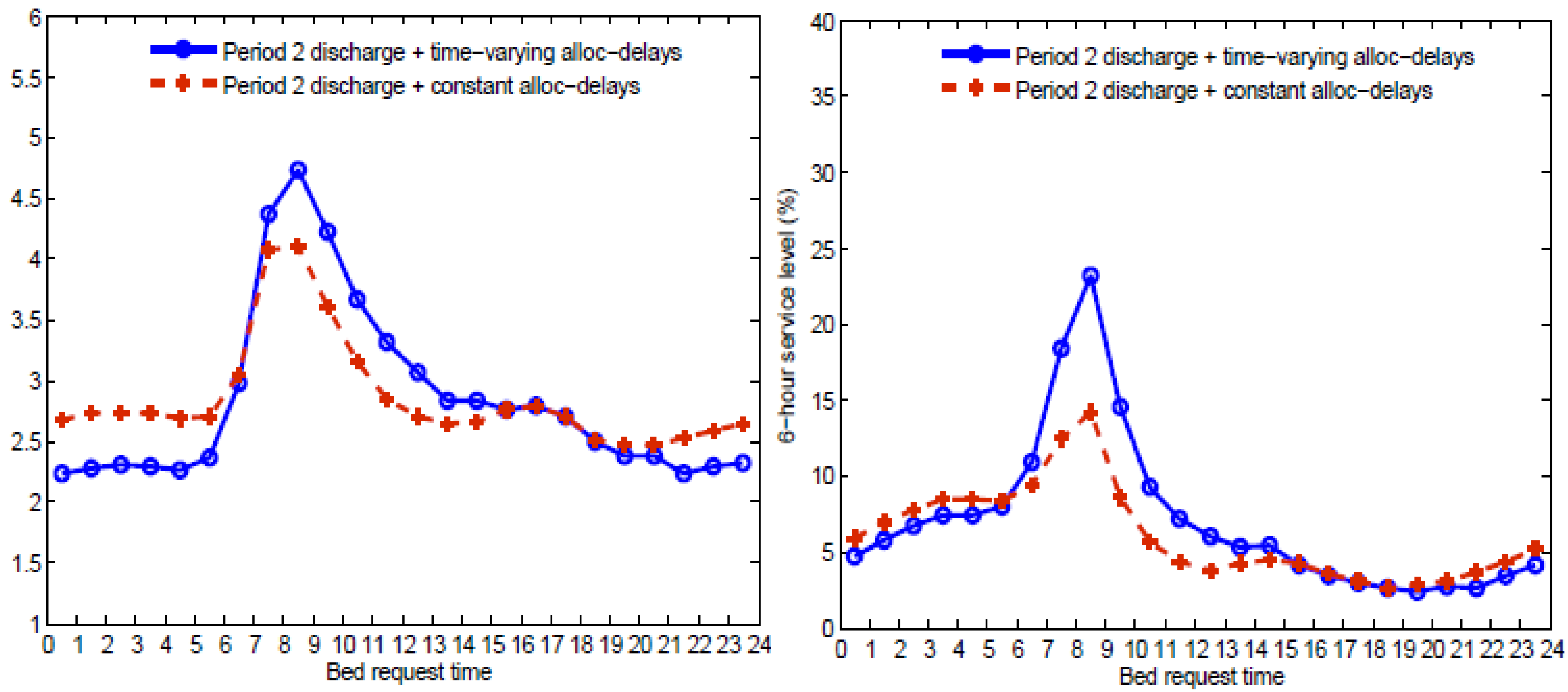




Only smooth the allocation delays

- Assuming allocation delay has a constant mean

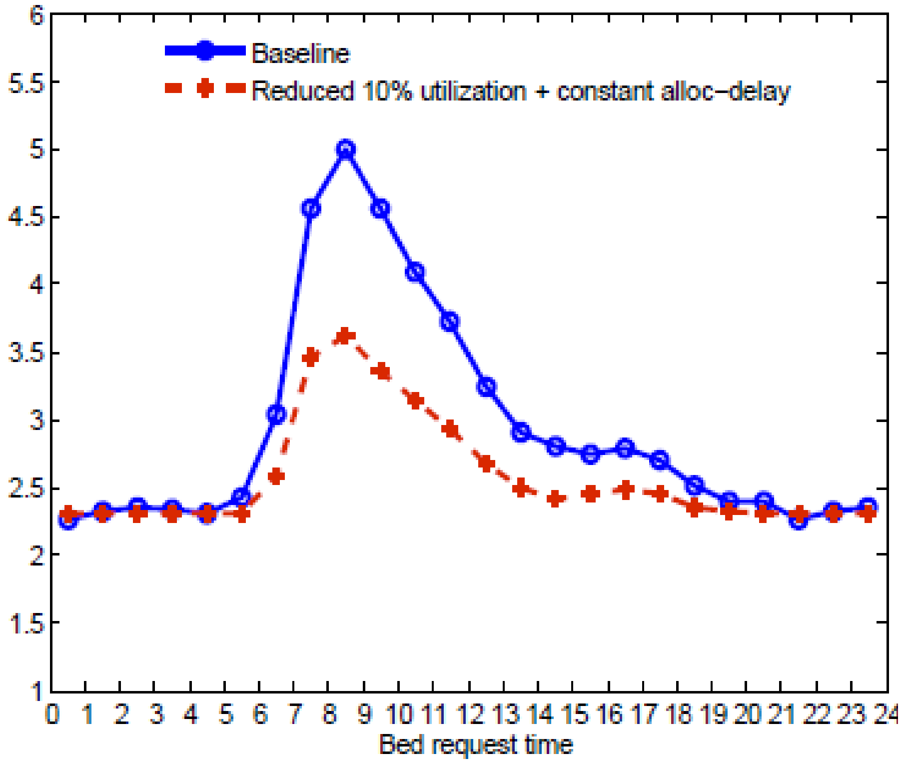
(a) hourly avg. waiting time (b) 6-hour service level



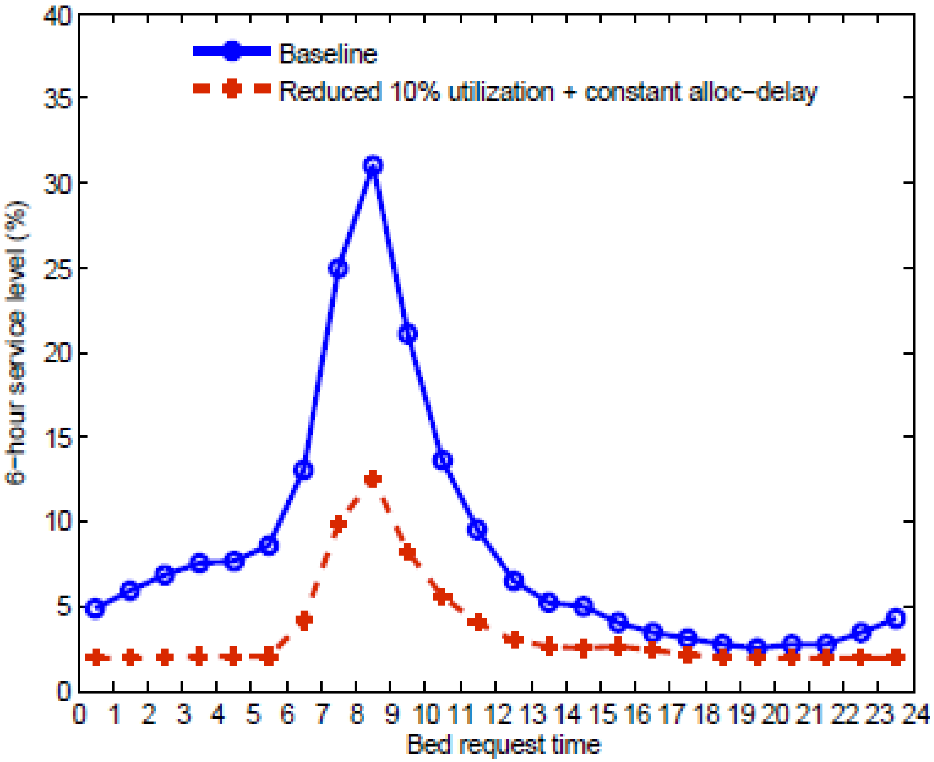
Impact of capacity increase

- 10% reduction in utilization, plus assuming allocation delay has a constant mean

(a) hourly avg. waiting time



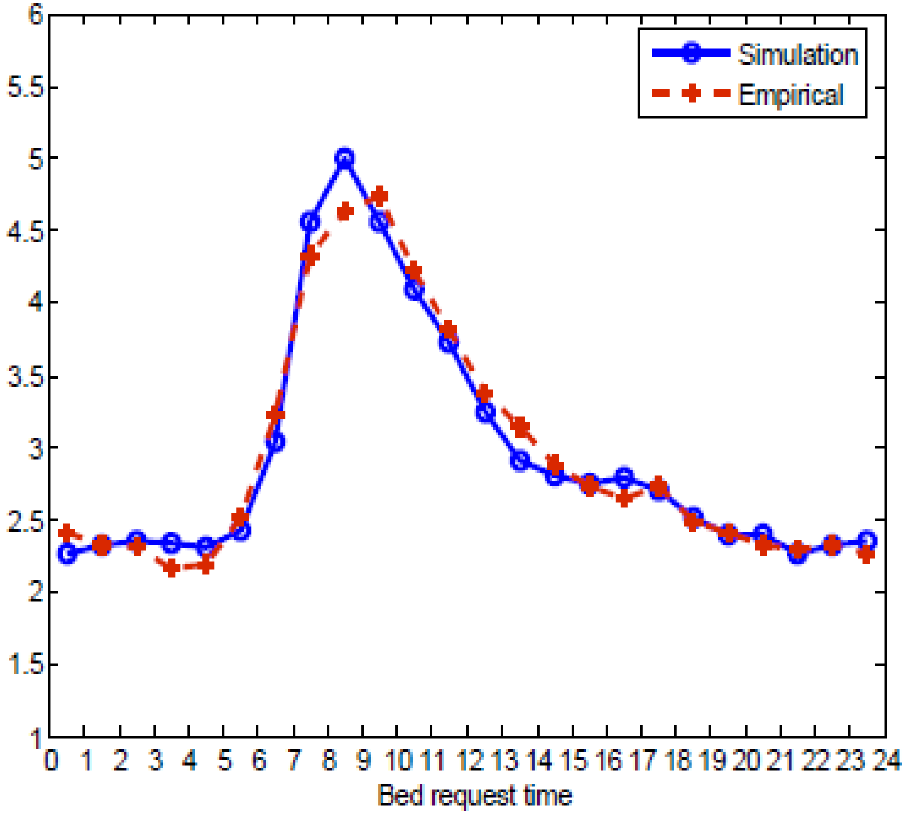
(b) 6-hour service level



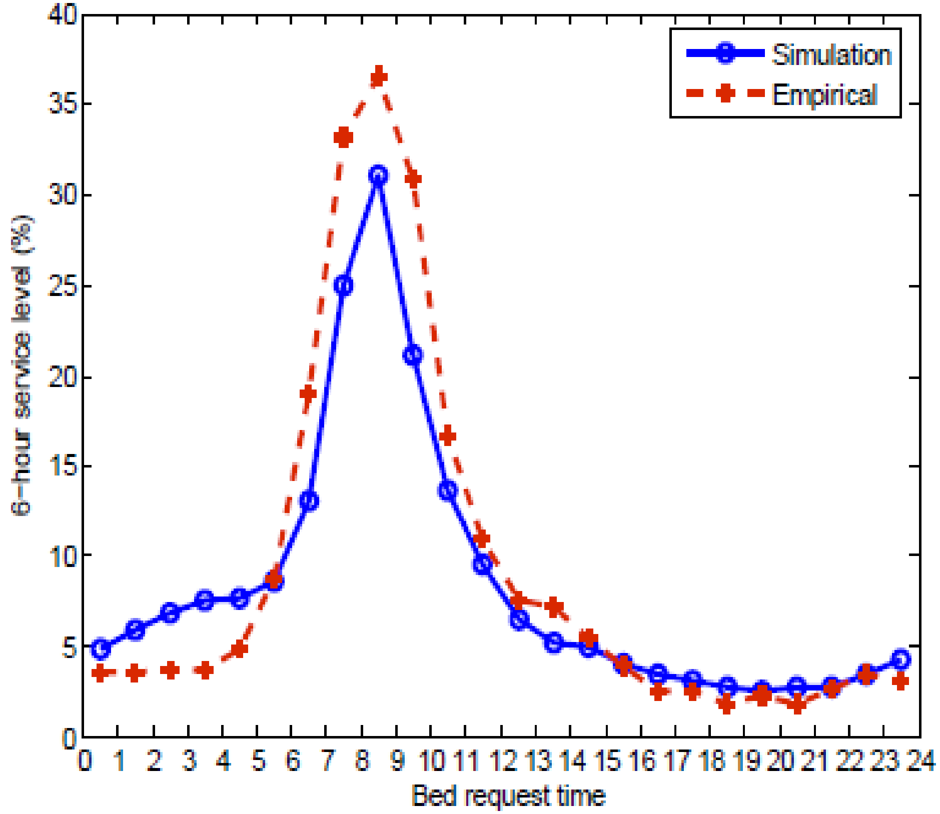
Simulation replicates most performance measures

- Hourly waiting time performances

(a) Hourly average waiting time

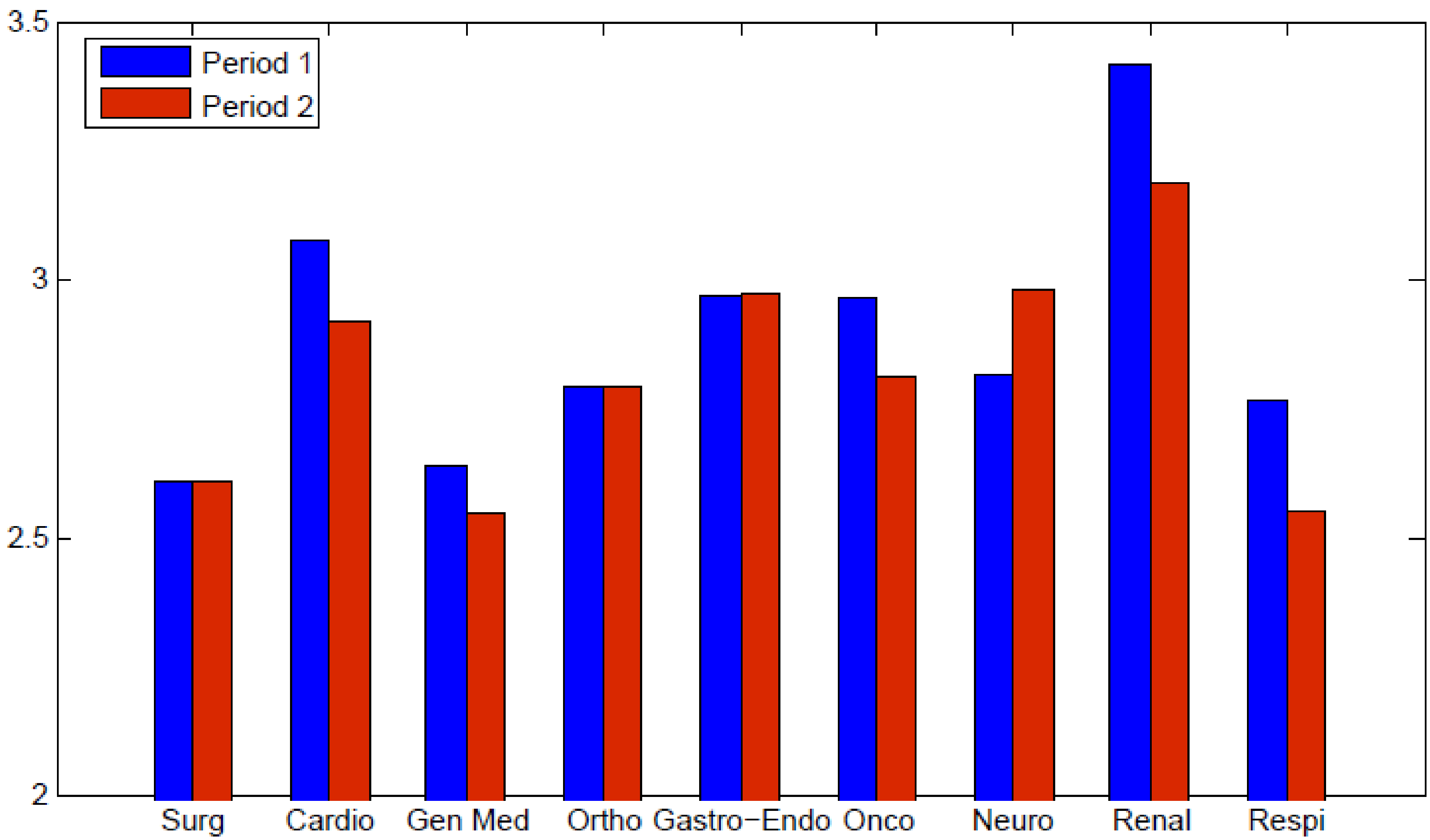


(b) Hourly 6-hour service level



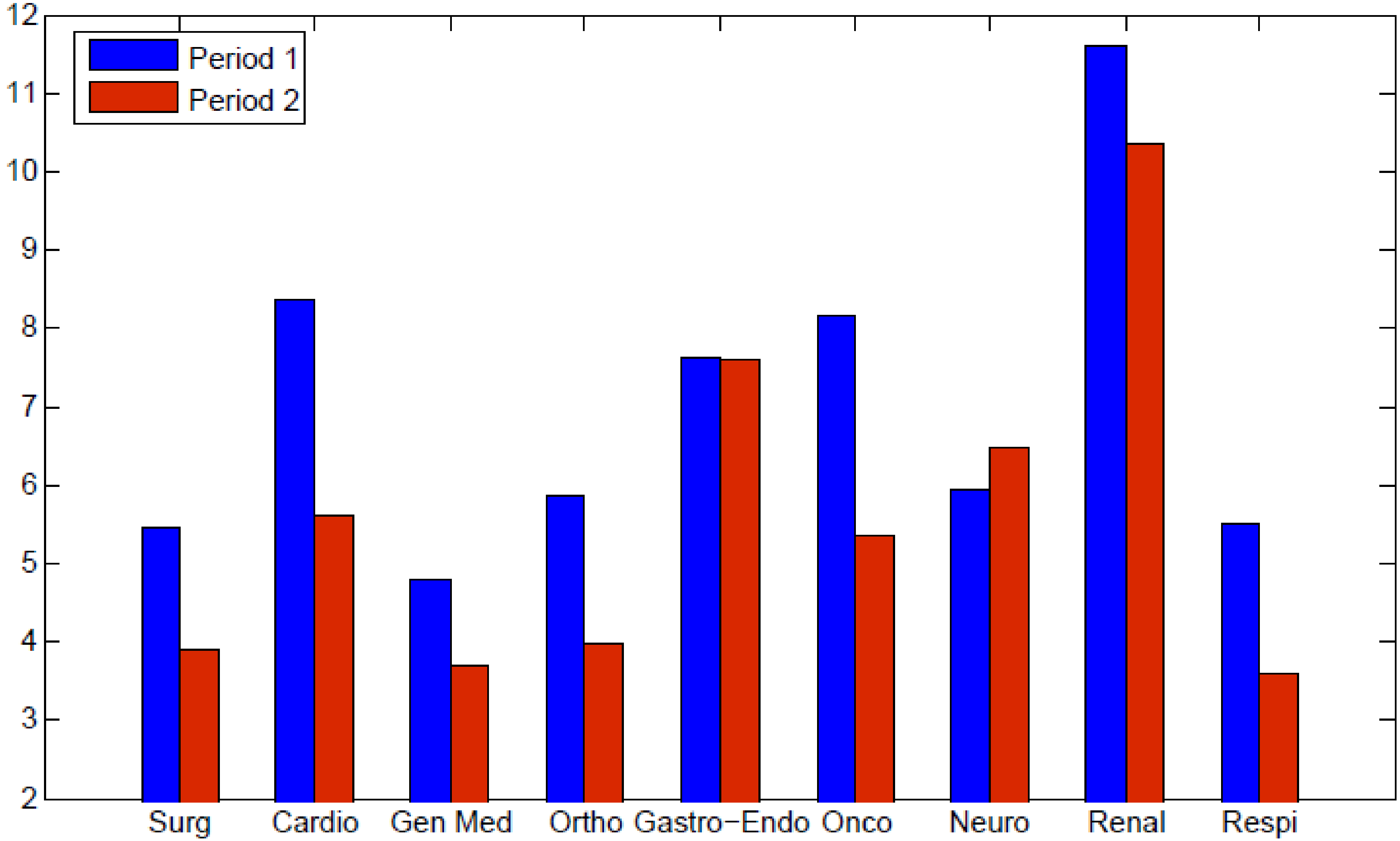
Average waiting time for each specialty

- Renal patients have longest average waiting time



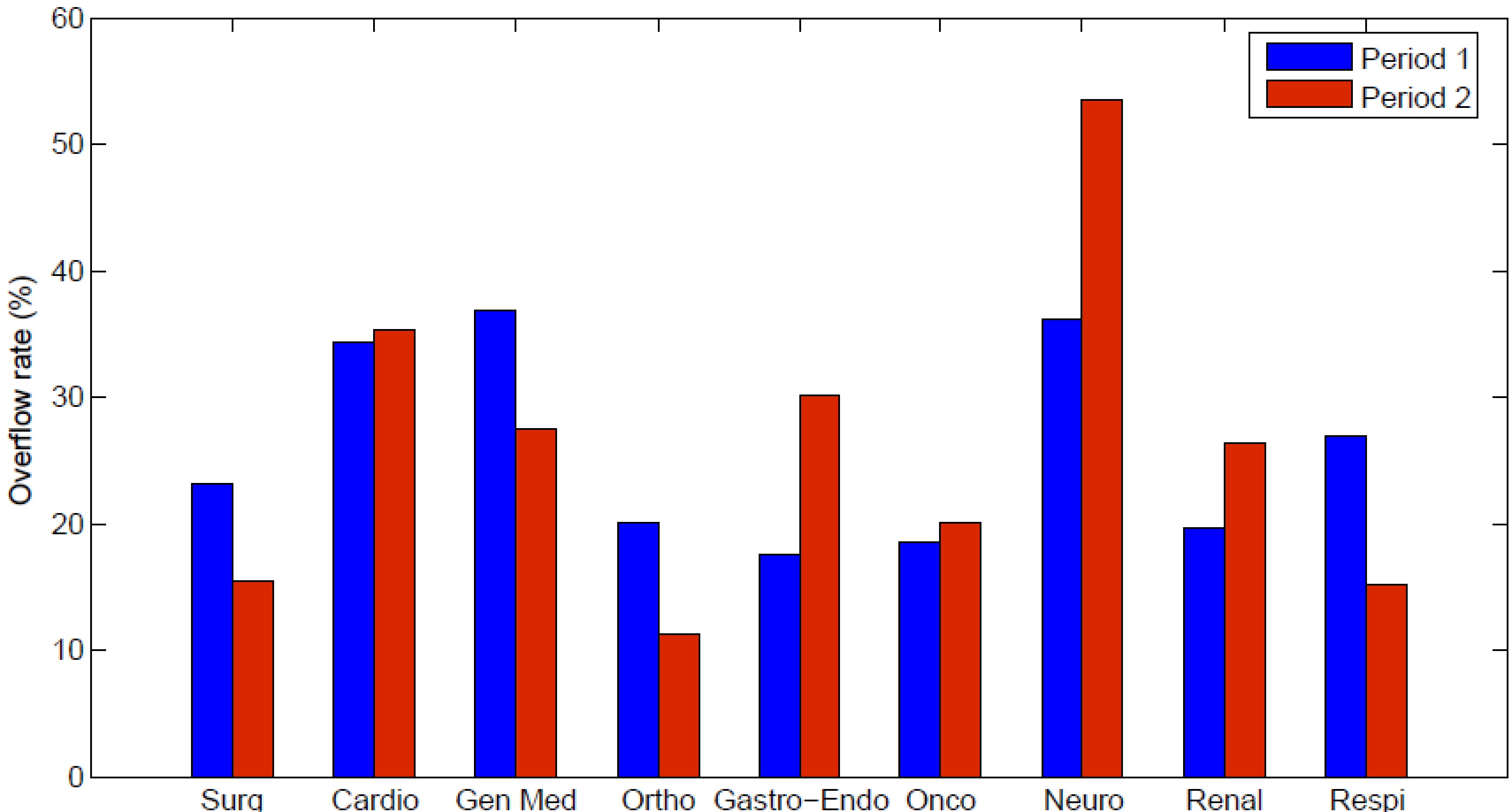
6-hour service level for each specialty

- Cardio and Oncology patients show significant improvement in the 6-hour service level



Overflow rate

- Overall overflow rate reduces in Period 2



Summary

- Conduct an empirical study of patient flow of the entire inpatient department
- Build and calibrate a stochastic model to evaluate the impact of discharge distribution on waiting for admission to ward
- Identify allocation delays as a second source of bottlenecks
  - Staffing appropriately in BMU, ED and Ward
- Achieve stable waiting time by aggressive early discharge + smooth allocation delay

Limitations

- Simulation cannot fully calibrate with the overflow rate
  - Bed class (A, B, C)
  - Gender mismatch
  - Hospital acquired infections
    - Example: a female Surg patient has to be overflowed to a Med ward, since the only available Surg beds are for males

- Day-of-week phenomenon
  - Admission and discharge both depends on the day of week
  - LOS depends on admission day
  - Performances (BOR, waiting time) varies among days

Questions?