Shift Effect in Emergency Departments

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# Background: Pay-for-Performance Program (P4PP) in Ontario

- Emergency Departments are experiencing long waiting time in Canada
  - *Canada has the worst ER wait times in 11 developed countries (Toronto Sun, February 16, 2017)*
- In 2008, the Ontario Ministry of Health and Long-Term Care launched P4PP to reduce waiting
- Performance is measured based on the 90th percentile of
  - Length of stay (LOS)
  - Time to physician initial assessment (TPIA)
  - Time to inpatient bed
  - Ambulance off-load time

Patient Flow and Performance Measures
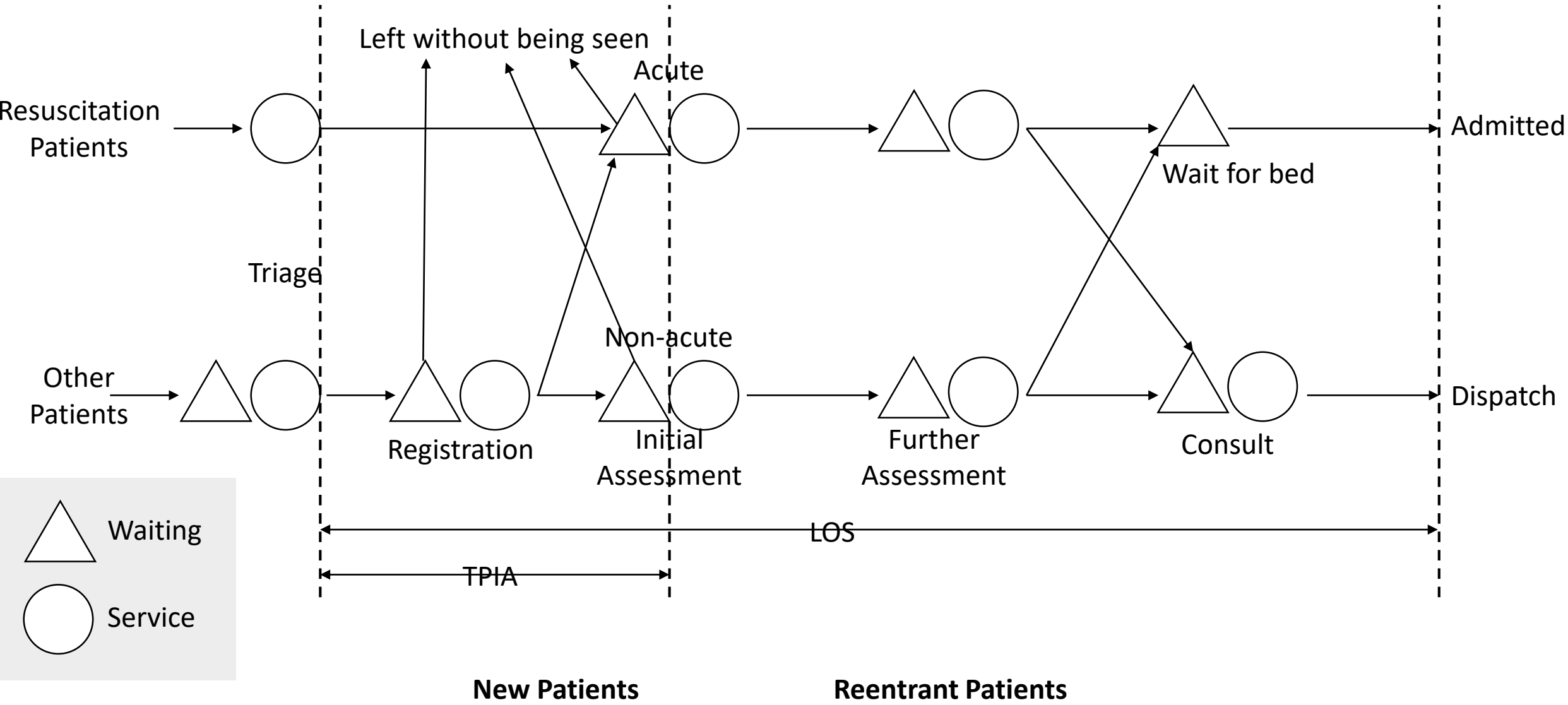
ED Redesign in Southlake Regional Health Center

- Implemented in Southlake RHC in June, 2011
- Huge improvement in TPIA: ranked first among 73 EDs in Ontario
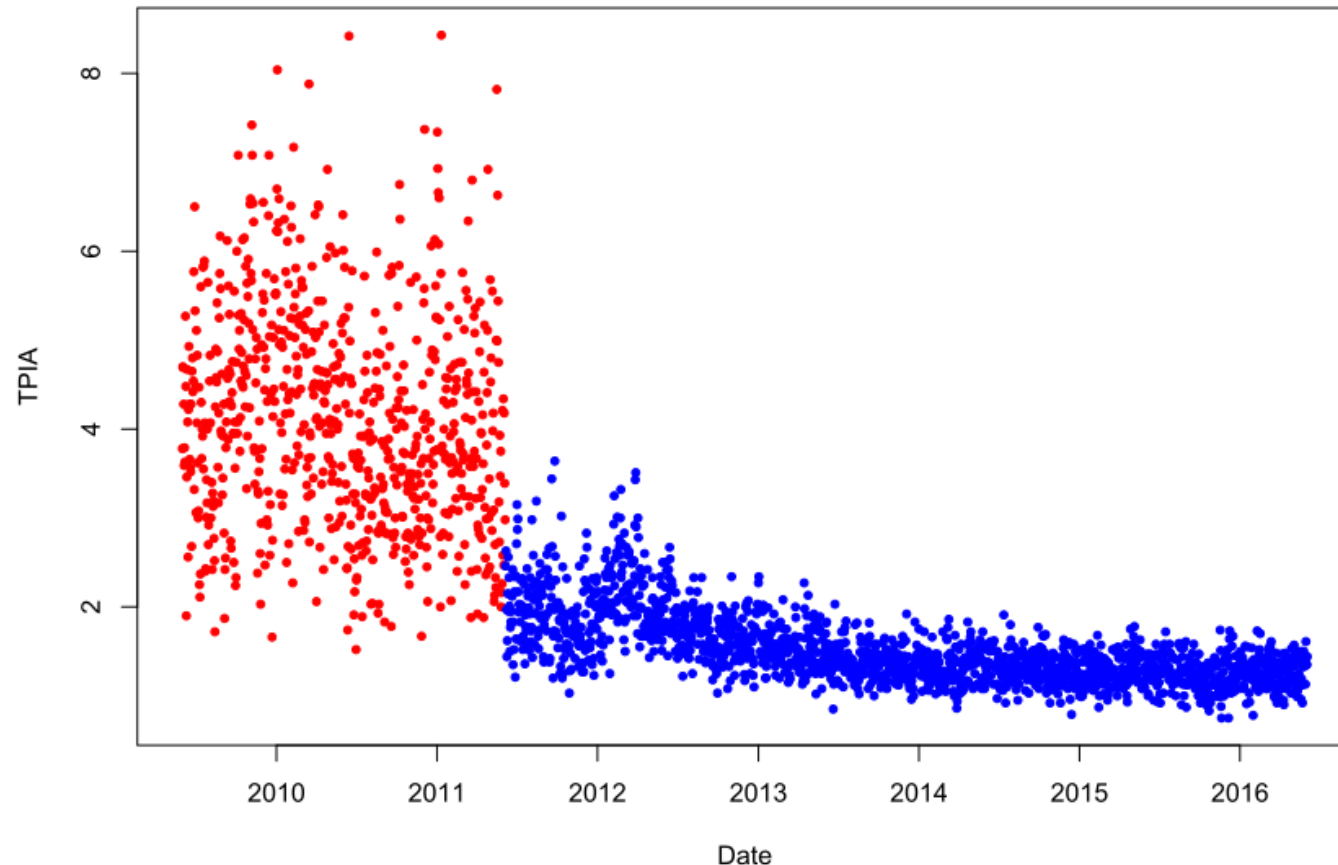
Traditional Viewpoint

- Shanthikumar & Yao (1992) shows a classical result for multi-class service system:
  - To optimize the *expected* performance measure of a certain class, absolute priority should be given to that class over all other classes
- For example,
  - To minimize the expected waiting time of Amazon Prime customers, always prioritize their orders
  - To reduce the expected service delay of cloud computing, prioritize corporate users over personal users
- So, Southlake must have prioritized new patients!
- On the contrary, priority was given to **reentrant** patients

TPIA is Measured at 90th Percentile

- In P4PP, KPI is the 90th percentile of TPIA
- Variance has a big influence on the 90th percentile
- Hypothesis: Prioritizing reentrant patients reduces the variance of TPIA
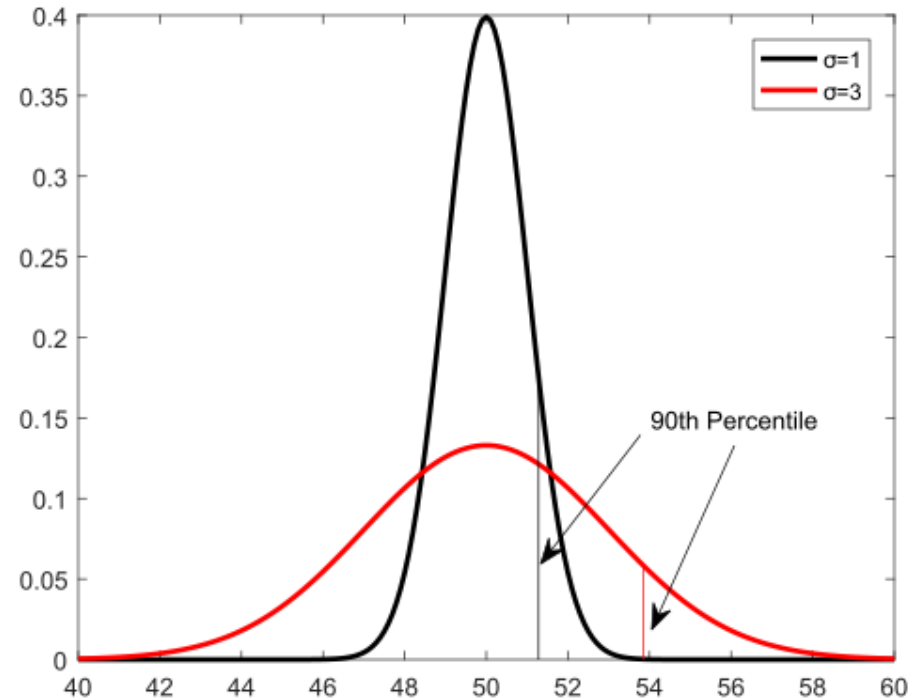
A Queueing Model

- Without enforcing any priority rule, the physician will schedule herself
- At any time, she could choose to see new (N) or reentrant (R) patients
- In Southlake, many ED physicians are paid on fee-for-service basis: by the number of patients served
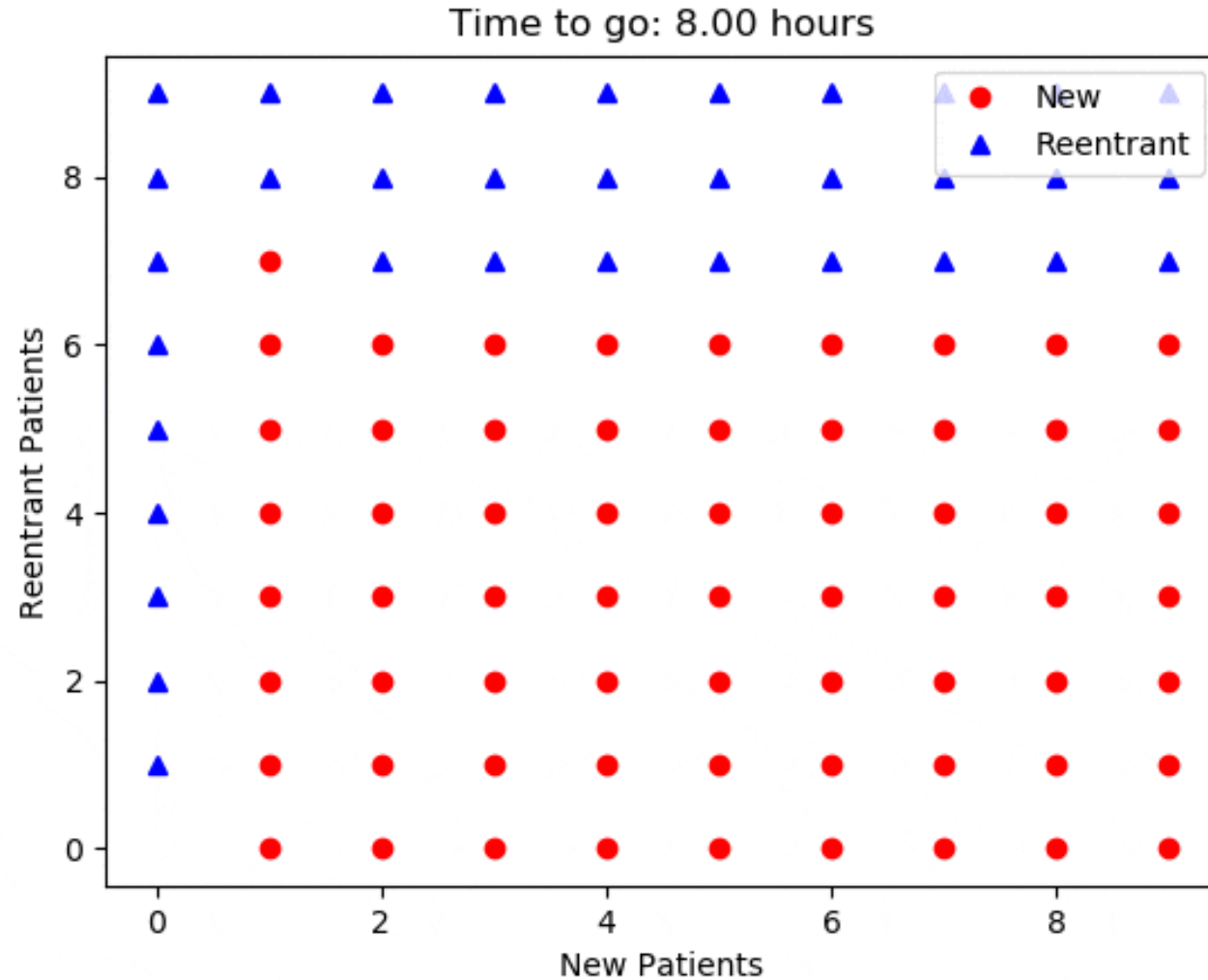- What's her optimal strategy?
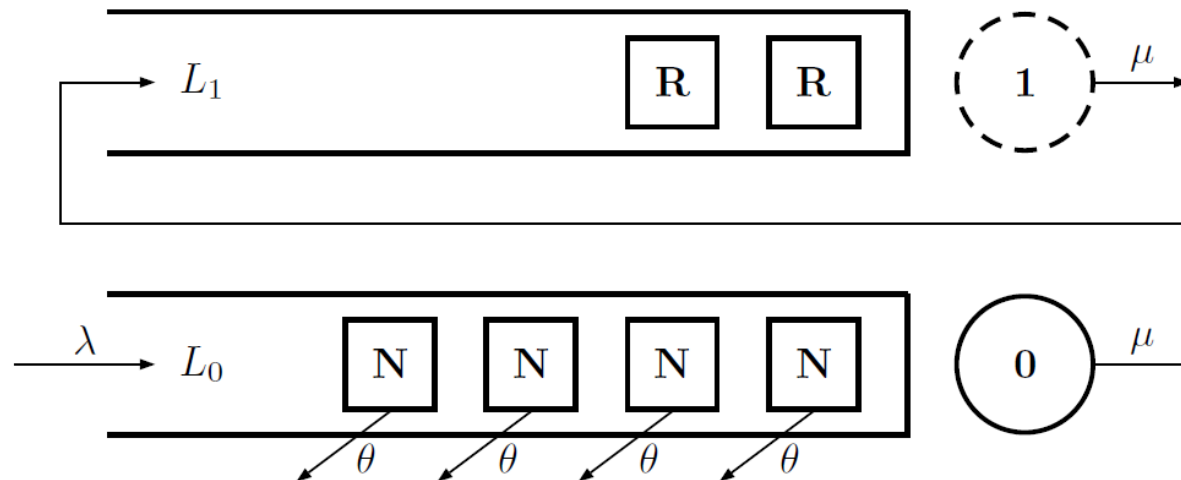
Optimal Strategy: Time Pattern

- We use $J_0(L_0, L_1, t)$ and $J_1(L_0, L_1, t)$ to denote the revenue of seeing new patients and reentrant patients

- L_0: number of new patients; L_1: number of reentrant patients

- Here t is "time-to-go": how many hours left before the shift ends

Optimal Strategy: Time Pattern
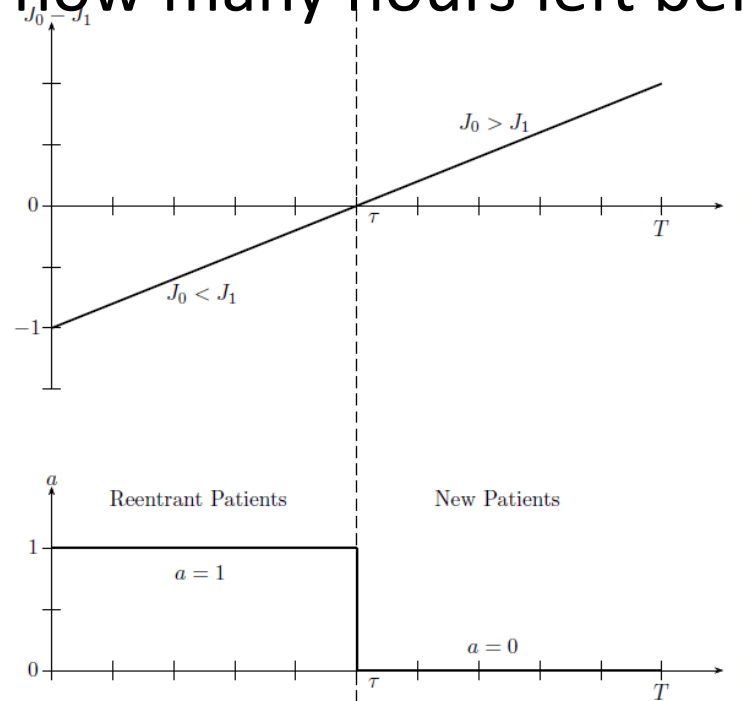
Optimal Strategy: Time Pattern

Shift Effect in ED

- The physician uses time as a "resource": she needs to maximize revenue using remaining time in the shift

- The optimal strategy has a time-dependent pattern. It has two phases:
  - At the first phase of a shift, the physician exclusively sees new patients (Storage)
  - At the second phase of a shift, she exclusively departures reentrant patients (Realize Revenue)

- New patients arriving in the first phase experience shorter TPIA, while those arriving in the second phase experience excessively long TPIA

- This increases variance of TPIA and results in large 90th percentile of TPIA
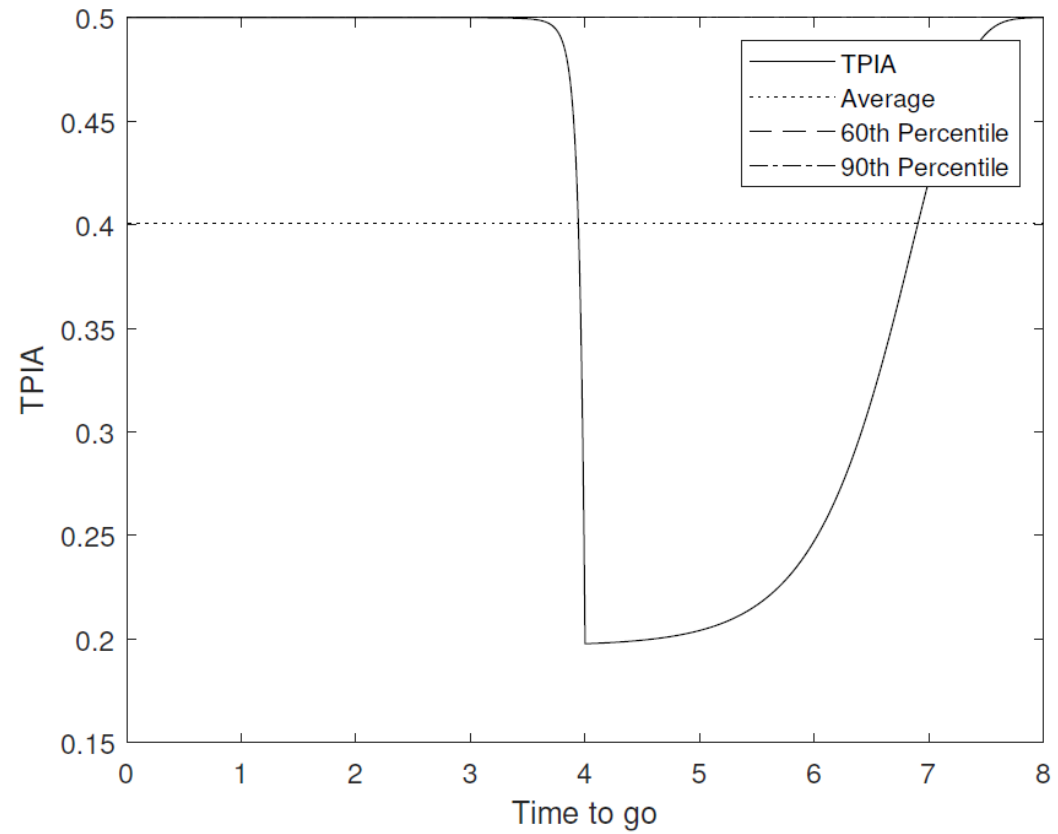
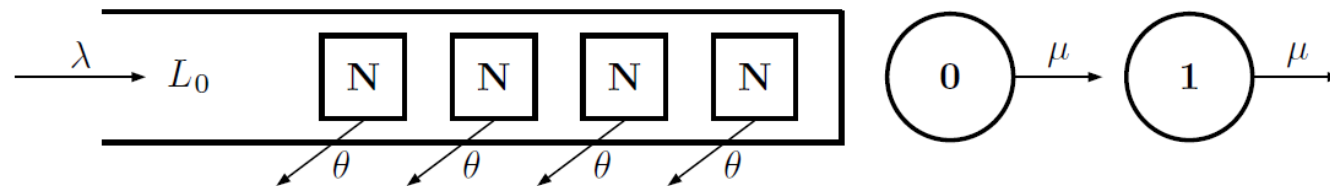# Effect on TPIA
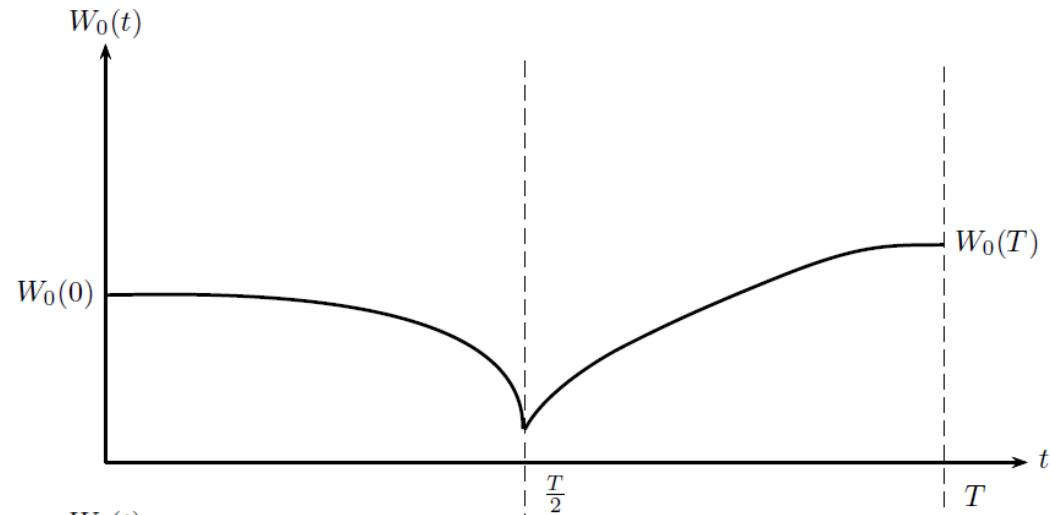
Workload (or number) of new patients
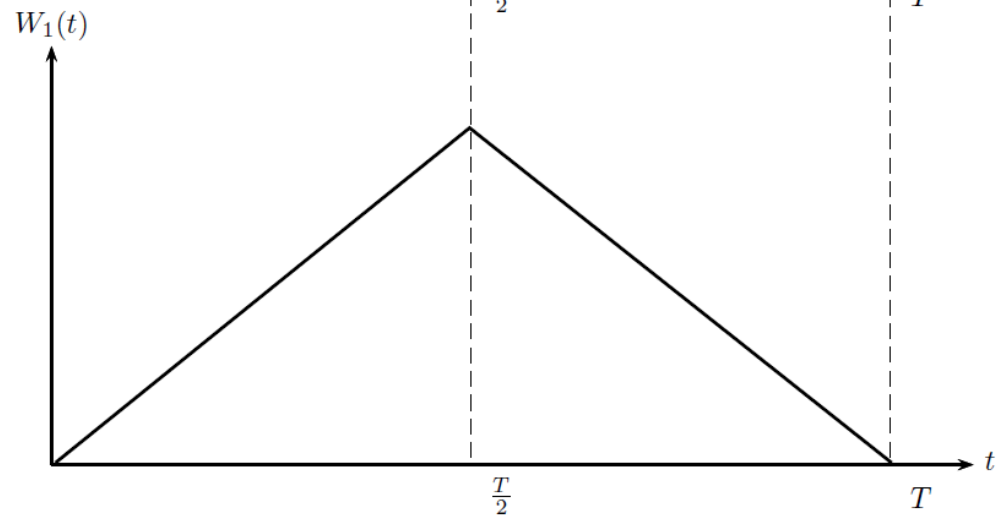
Workload (or number) of reentrant patients

Pattern of TPIA within a Shift

Benchmark against Serial System

- We consider an benchmark system where patients receive two assessments in series

- That is, whenever there is a new patient finishing first assessment, the physician must see him before she can start a second new patient

- Result: for any p>50, the pth percentile of TPIA of the serial system is smaller than self-schedule system; no first order difference in physicians' revenue

Conclusion

Physician

ED Manager

Maximize Throughput ←----- Solution?
Prioritize Reentrant
Flexible Overlapping Shift -----→ Longer 90th Percentile of TPIA

Finite Shift Length

Higher Variability

Two-phase Strategy → Temporal Waiting Time Pattern

Externality
Less Funding
Worse Medical Outcome
Potential Lawsuit Problem
Reduced Arrival