Discussion
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PhD Technion, 2010
With Avishai Mandelbaum

Thesis: “Queues in Hospitals: Queueing Networks with Reentrant Customers in the QED Regime"
Daily arrival rate (by month) to Emergency Department
Hourly arrival rate to Emergency Department

![Graph showing hourly arrival rate to Emergency Department](image)
The Erlang-R Queue:

Time-varying QED Queueing network with Reentrant customers in support of personnel staffing
Operational performance measures in healthcare:
- Timely service (Waiting): $P(W_t > \tau)$, $E[W]$
- Left Without Being Seen (Abandonment): $P(A_t)$
- Ambulance diversions percentage (Blocking): $P(B_t)$

Underlying assumption: Operational system performance and quality-of-care are related.

The (time-varying) square-root formula:
$s(t) = m(t) + \beta \sqrt{m(t)}$

The time-varying offered-load function ($m(t)$) is determined by an $M_t/G/\infty$ network
Challenges in Applications

Many server approximations; Are they good for small systems?

P(wait) in ED using time-varying staffing and MOL approximation

Large systems (90 servers) vs Small Systems (1-7 servers)

Average of 100 replications.
Other Methods

**PSA (Pointwise Stationary Approximation), Lag-PSA**

OL: \( m(t) = E[\lambda(t - S_e)] E[S] \)

PSA: \( m(t) \approx E[\lambda(t)] E[S] \)

Lag-PSA: \( m(t) \approx \lambda(t - E[S]) E[S] \)

When service time is very long and/or has a special structure (like returns or interruptions) PSA could be vary bad; [GKW (2007) survey]
IS vs. PSA when customers re-enter service ("Erlang-R" model)
Conclusion

- Time-varying queues are real
- They are here to stay
- They need to be take into account
- Proposed methods are effective

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Thank You