Strategic Double-Booking & its Impact on Healthcare Operation

Arseniy Gorbushin, Olga Bountali, Opher Baron, and Binyamin Oz

Arseniy.Gorbushin@Rotman.Utoronto.Ca, Olga.Bountali@Rotman.Utoronto.Ca,Opher.Baron@Rotman.Utoronto.Ca, and b.oz@huji.ac.il

[1] Rotman School of Management, University of Toronto, Toronto ON

[2] The Hebrew University of Jerusalem, Jerusalem Israel

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Rotman School of Management
UNIVERSITY OF TORONTO

1

Strategically Double-Booking Appointments

Patients are shopping around trying to receive the COVID-19 vaccine faster

2

Cancel the Extra Appointment Or Maybe Not?

Strategic Double-Booking Results in No-Shows

Neli Trevisan🌻
@neli_trevisan · Follow

Replying to @DocMCohen

It took me over 1 hour to cancel my multiple registrations and 2 bookings with the provincial system. The provincial system doesn't give an online option to cancel a booking, so one needs to call and stay on hold for over 40 minutes (in my case). The system is chaotic.

10:12 AM · Jun 16, 2021

♡ 93   💬 Reply   🔗 Copy link

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meh.
@marmalade · Follow

Replying to @DocMCohen

Its REALLY hard to cancel the Ont bookings. You cant do it online; you have to call in - if you can get past the busy signal (it took me 6 hrs of trying), you then have to wait ~30min to actually to get to a person who can cancel it for you. Not everyone has the time or patience.

10:15 AM · Jun 16, 2021

♡ 7   💬 Reply   🔗 Copy link

Read 1 reply

Linda McCallum
@LindaMcCallumRE · Follow

Replying to @DocMCohen

It is impossible to cancel a 2nd pre-booked appointment via the Provincial Portal if you managed to get your second shot at a drug store faster. The 2 systems do not communicate with one another(provincial & Drug stores). You need to call the # and try to get through. Frustrated

5:47 AM · Jun 17, 2021

♡ 1   💬 Reply   🔗 Copy link

Explore what's happening on Twitter

Michelle Cohen, MD ✓ · Jun 16, 2021
@DocMCohen · Follow

No-shows for 2nd doses are becoming a problem. Ppl book multiple appts and then don't cancel.

We can't just put mRNA vaccine back in the fridge. If you no-show you are forcing us to scramble or throw unused vaccine away.

Don't be a 2nd dose jerk! Cancel your extra appts!

Daniel Perez
@Daniel_FPerez_ · Follow

Sorry to bug you but do you have any tips on how? My parents can't seem to find a way to cancel online and haven't been able to get less than a 2 hour hold time on the phone... Just wondering if there's something I've missed to point them to. I'll keep looking but just in case!

9:45 AM · Jun 16, 2021

♡ 68   💬 Reply   🔗 Copy link

Read 6 replies

Consequences of Double-Booking

- Double-Booking leaves capacity poorly utilized

  - Medical personnel do not have enough time to fill the missed slots

- Potentially jeopardizes patient health

  - E.g., a more needy patient could be seen earlier

- Increases staffing costs

  - USA healthcare system costs increase can reach up to $150 billions

Double-Booking Phenomenon: Broader Applicability

- Healthcare sector:
  - COVID-19 vaccination process in North America
  - Double-Booking for imaging and appointments with specialist (Europe)
  - Multi-listing for a donor transplant in the US
  - Booking multiple emergency providers in developing countries

- Ride hailing applications: Multihoming from the passenger side

- Manufacturing settings : Ordering from several unreliable suppliers

Research Objectives

- Model strategic double-booking and determine customer equilibrium behavior

- Quantify the impact of strategic double-booking on both hospital operations and patient outcomes

- Provide comparative benchmarks to inform provincial/local governments and policy makers in general

- Explore practical solutions to improve the hospital operation and patient outcomes

Literature Review

- No-shows in the medical and healthcare operations literature

  - Ding, Gupta, and Tang (2023), Liu et al. (2019), Luo, Kulkarni, and Ziya (2012), Hassin and Mendel (2008)

- Strategic customer behavior

  - Cui, Su, and Veeraraghavan (2019), Guo and Hassin (2015)

  - Baron and Economou (2022), Bountali and Economou (2019), Afeche and Sarhangian (2015), Guo and Hassin (2011), Burnetas and Economou (2007), Hassin and Haviv (2003)

- Load-balancing and redundancy queues

  - Nageswaran and Scheller-Wolf (2022), Gardner et al. (2017), Oh and Su. (2012)

# Customer Dilemma–How Many Queues to Join?
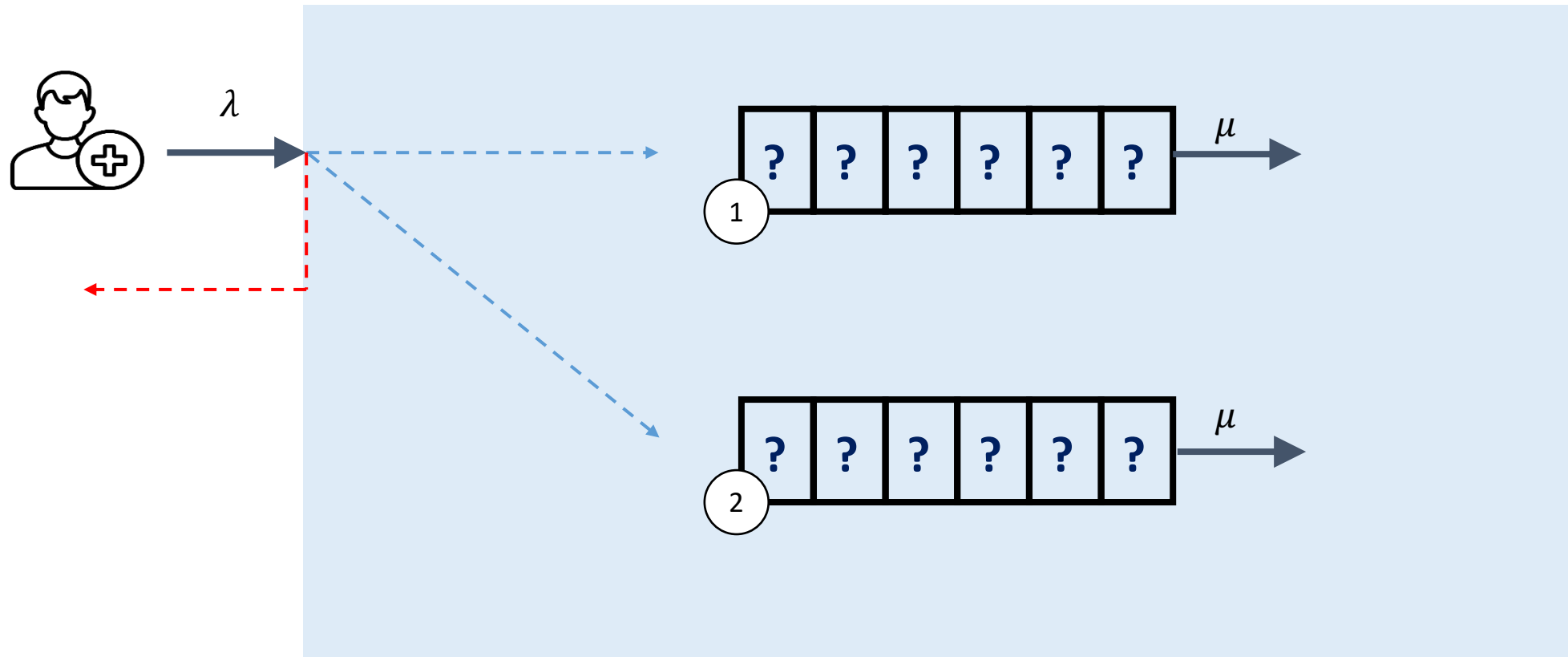
The Base Model

- Primitives
  - N distinct identical M/M/1 queues, each with
  - Arrival process ~ Poisson(λ)
  - Service times i.i.d. ~ $Exp(\mu)$

- Economic Parameters
  - Reward R
  - Waiting cost C per customer per time unit
  - Double-Booking cost d

- Decision Framework
  - Customers can Single-Book (**SB**), Double-Book (**DB**), or Balk (**B**)
  - If DB, they join their dedicated queue plus another arbitrary queue
  - If DB, they do not cancel the redundant appointment
  - Unobservable model

- Objective:
  - Customer's objective: Utility maximization
  - Social planner's objective: Effective throughput maximization (e.g., number of vaccinated patients)
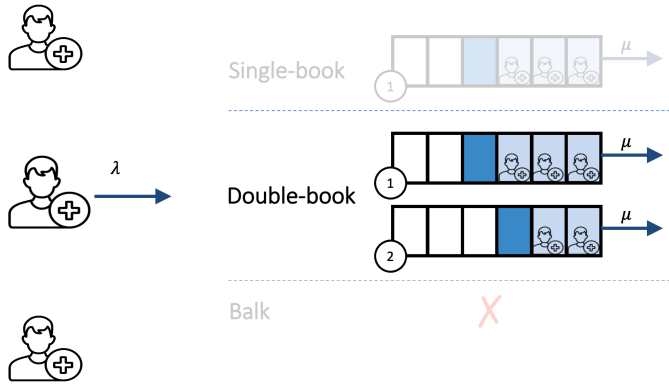
Customer Utility Function
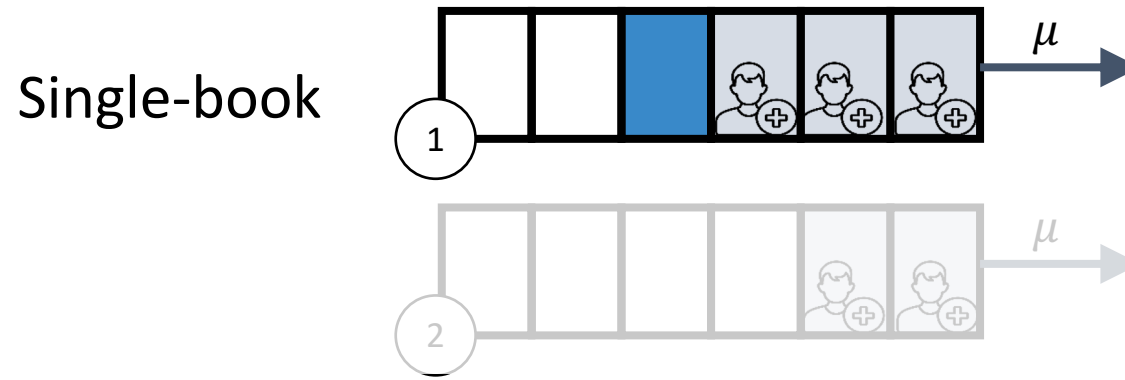
Single-book

$$U_{SB} = R - cES_1$$
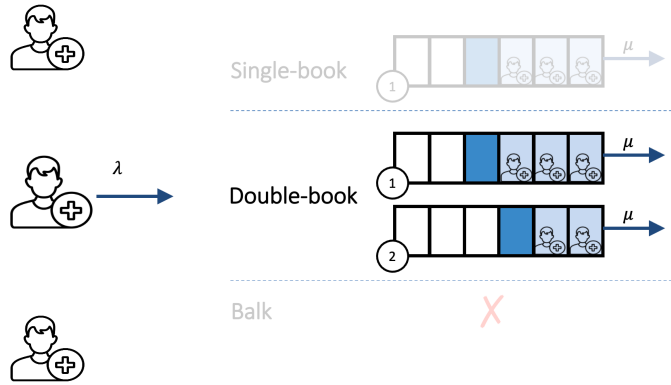
Double-book

$$U_{DB} = R - cE\{min(S_1, S_2)\} - d$$

Balk

$$U_B = 0$$
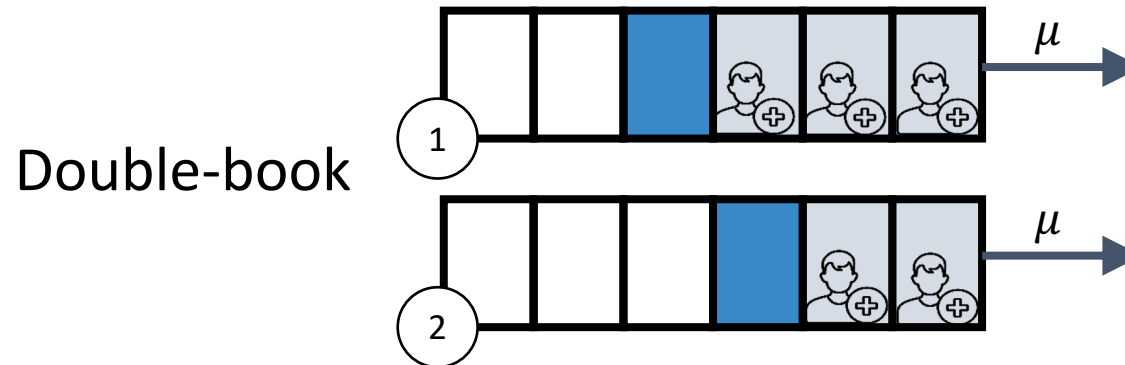
- N identical M/M/1 queues

- Hospital arrival processes and queue lengths are asymptotically independent
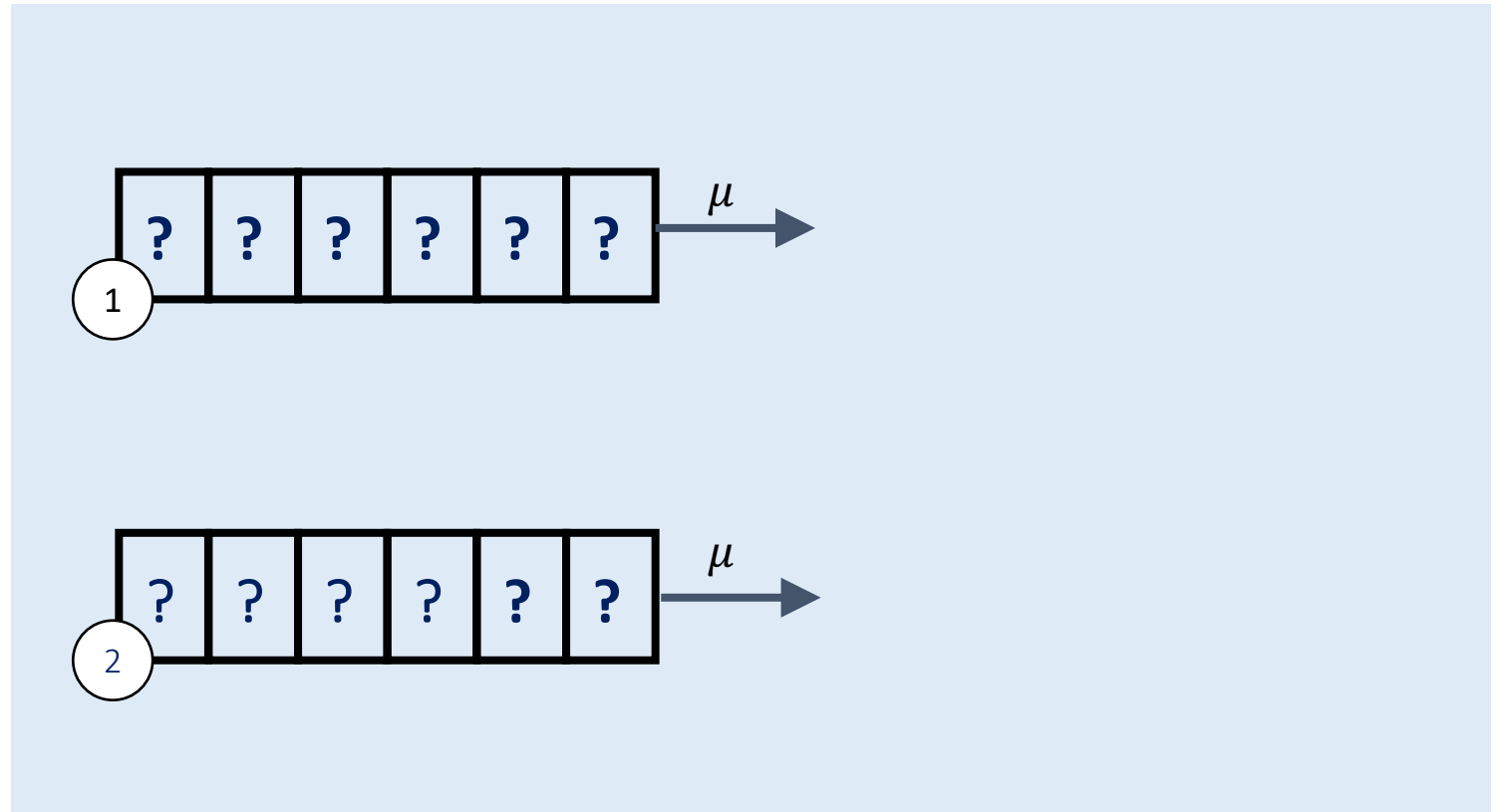
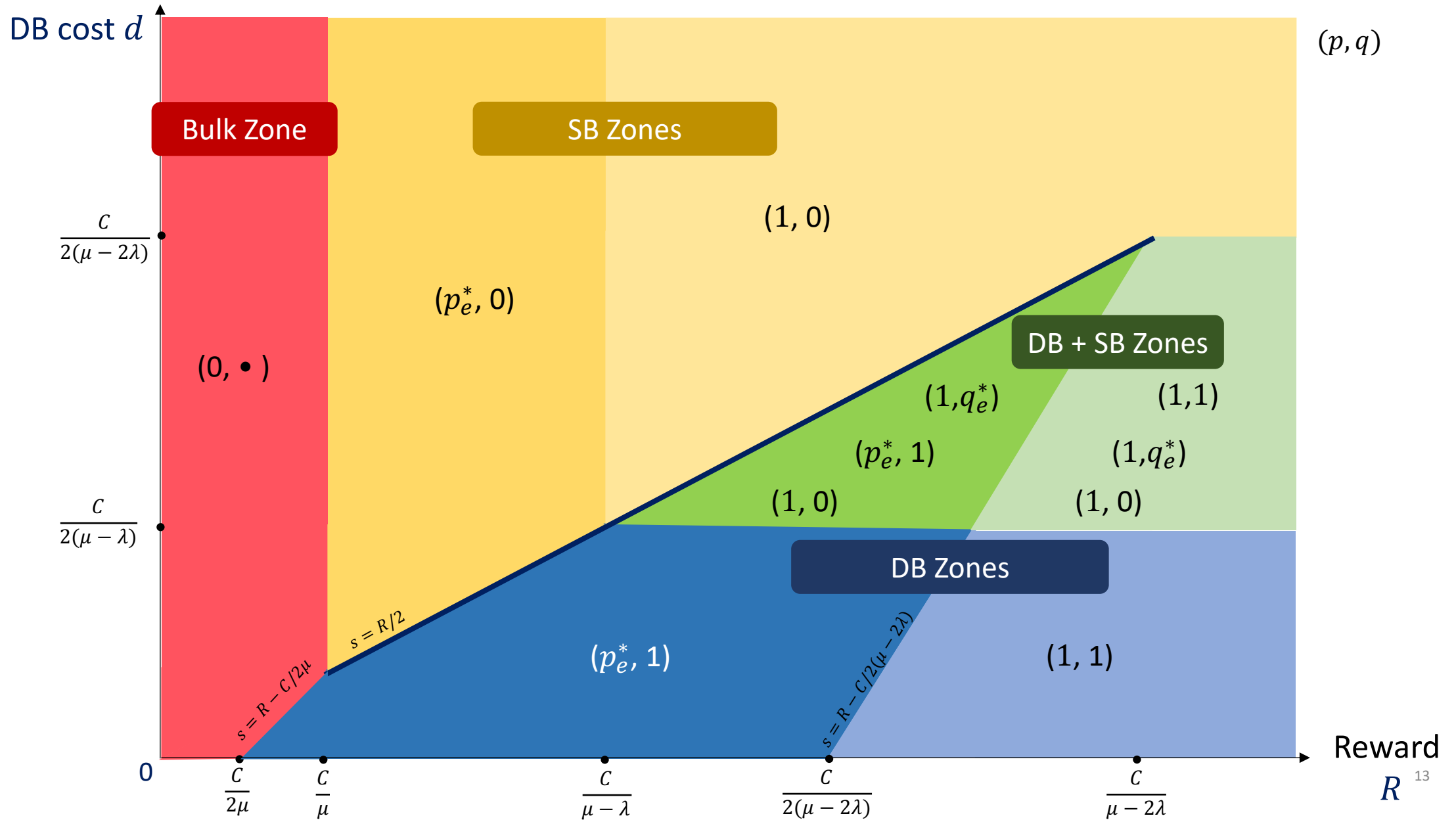- $Emin(S_1, S_2) = \frac{1}{2}E(S_1)$
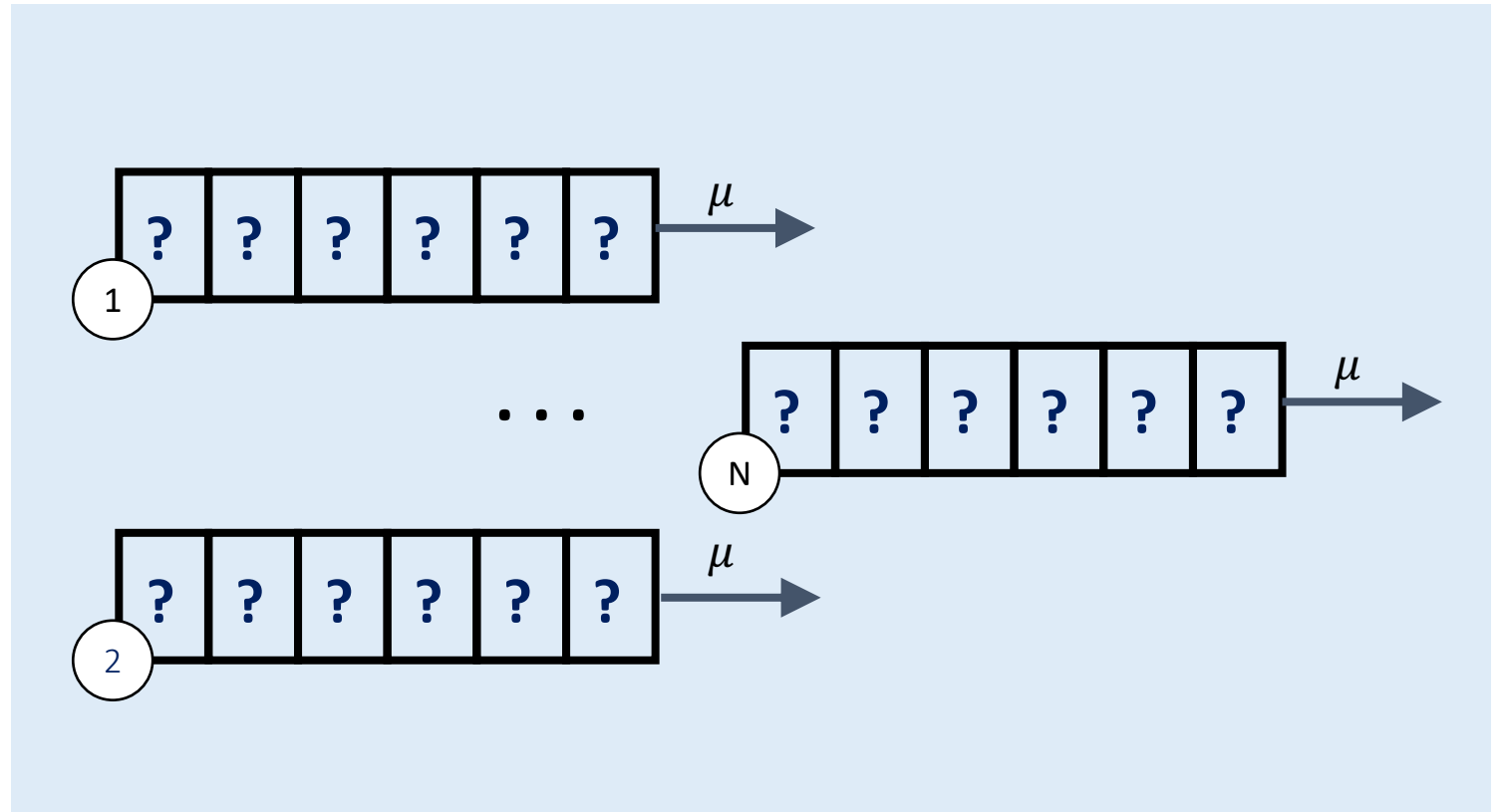
The Game: The Neighborhood Case--Two Queues

- 2 identical M/M/1 queues

- Hospital arrival processes and queue lengths are correlated

- If no one else double-books, then

$$Emin(S_1, S_2) = \frac{1}{2}E(S_1)$$

- If everyone double-books, then $Emin(S_1, S_2) = \dfrac{4 + \rho}{8}E(S_1)$
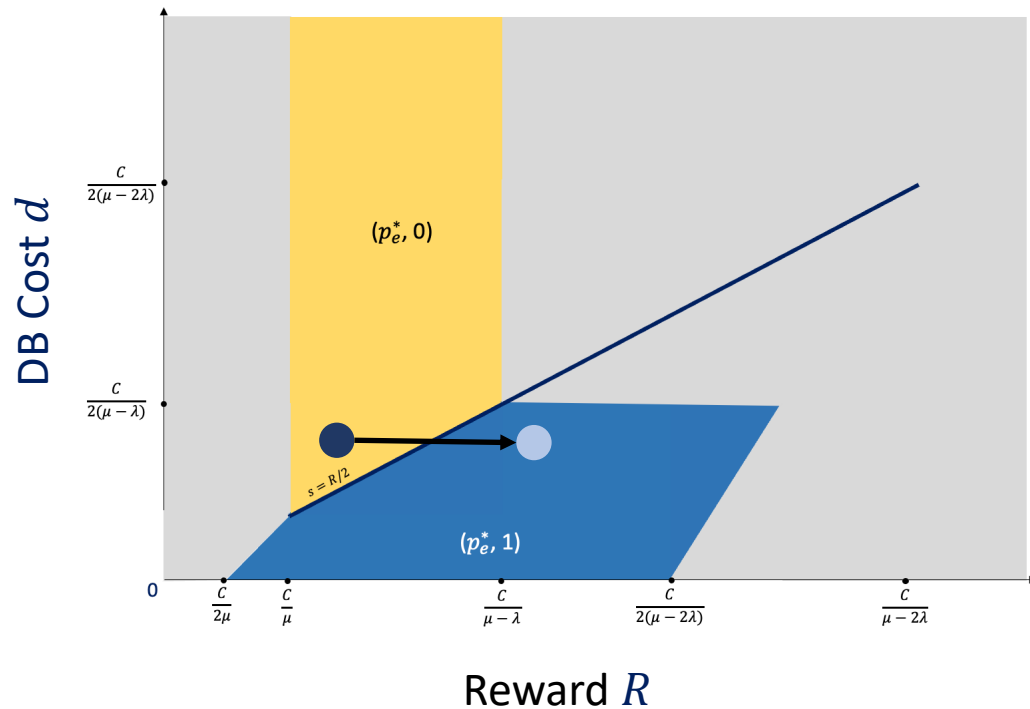
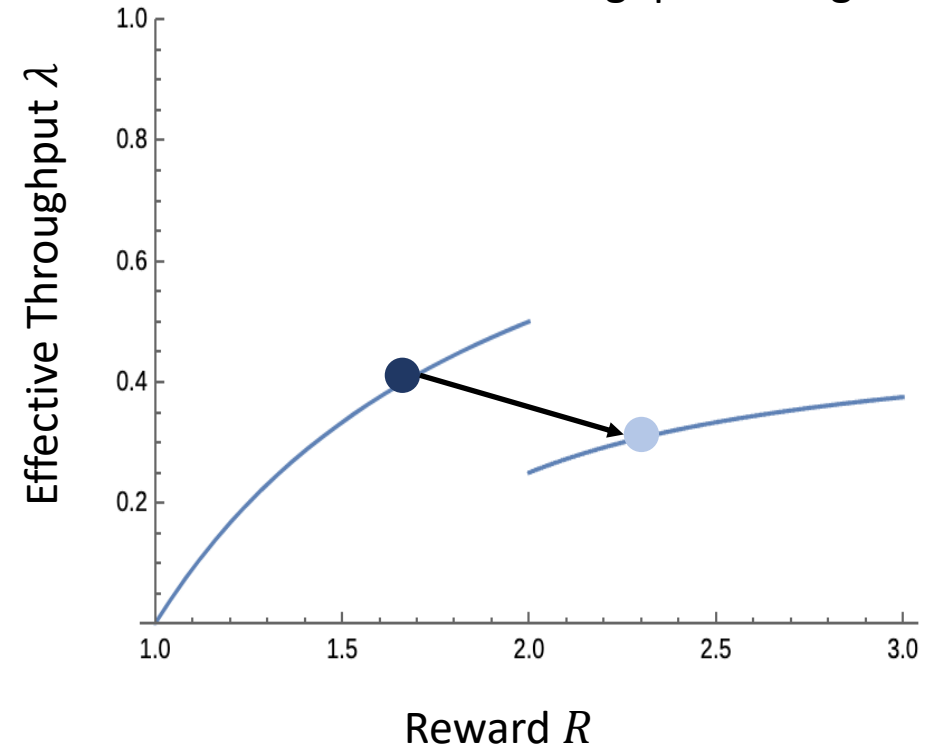# The City Case: Equilibrium Strategies – Case $\lambda < \mu/2$

The Effect of the Reward R
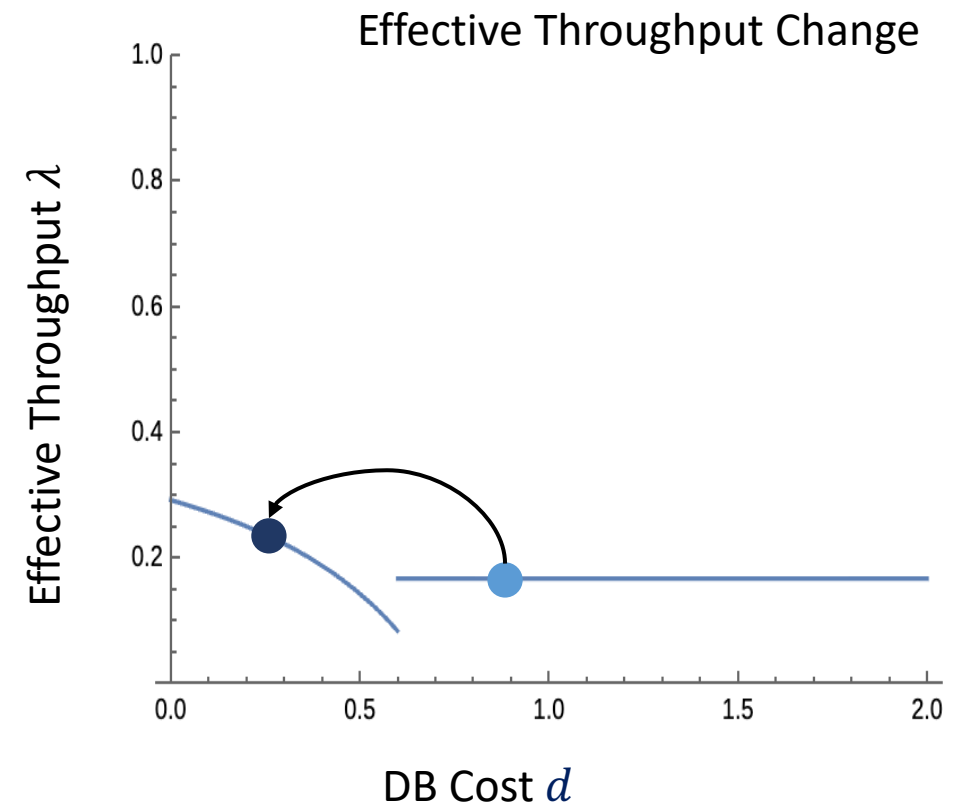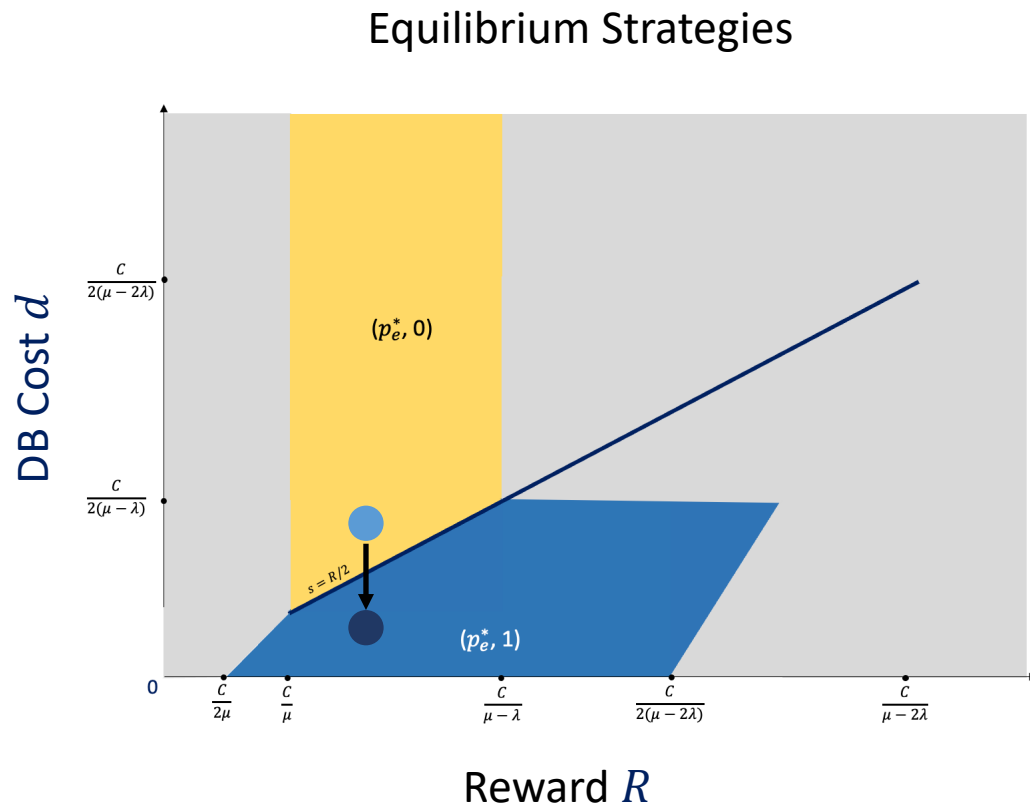

Equilibrium Strategies

Effective Throughput Change

- Increase in reward may switch patients from SB to DB

- DB creates waste of capacity which may lead to lower throughput (if the new reward is high enough)

The Effect of the DB Cost d

Equilibrium Strategies

Effective Throughput Change

- Decrease in DB cost d may switch patients from SB to DB
- In the low traffic, DB may increase throughput because waste of capacity is not an issue

Comparative Benchmarks

- **Centralized model:** The central planner sends patients at the shortest queue hospital

- **Cancellation model:** Patients double-book, but cancel the redundant appointment

- **Designated hospital model:** Patients are booked to a designated hospital and cannot book elsewhere
  - In Canada, the hospitals accepted patients based on postal codes requiring "proof of address"

Benchmark Comparison – Case $\lambda < \mu/2$
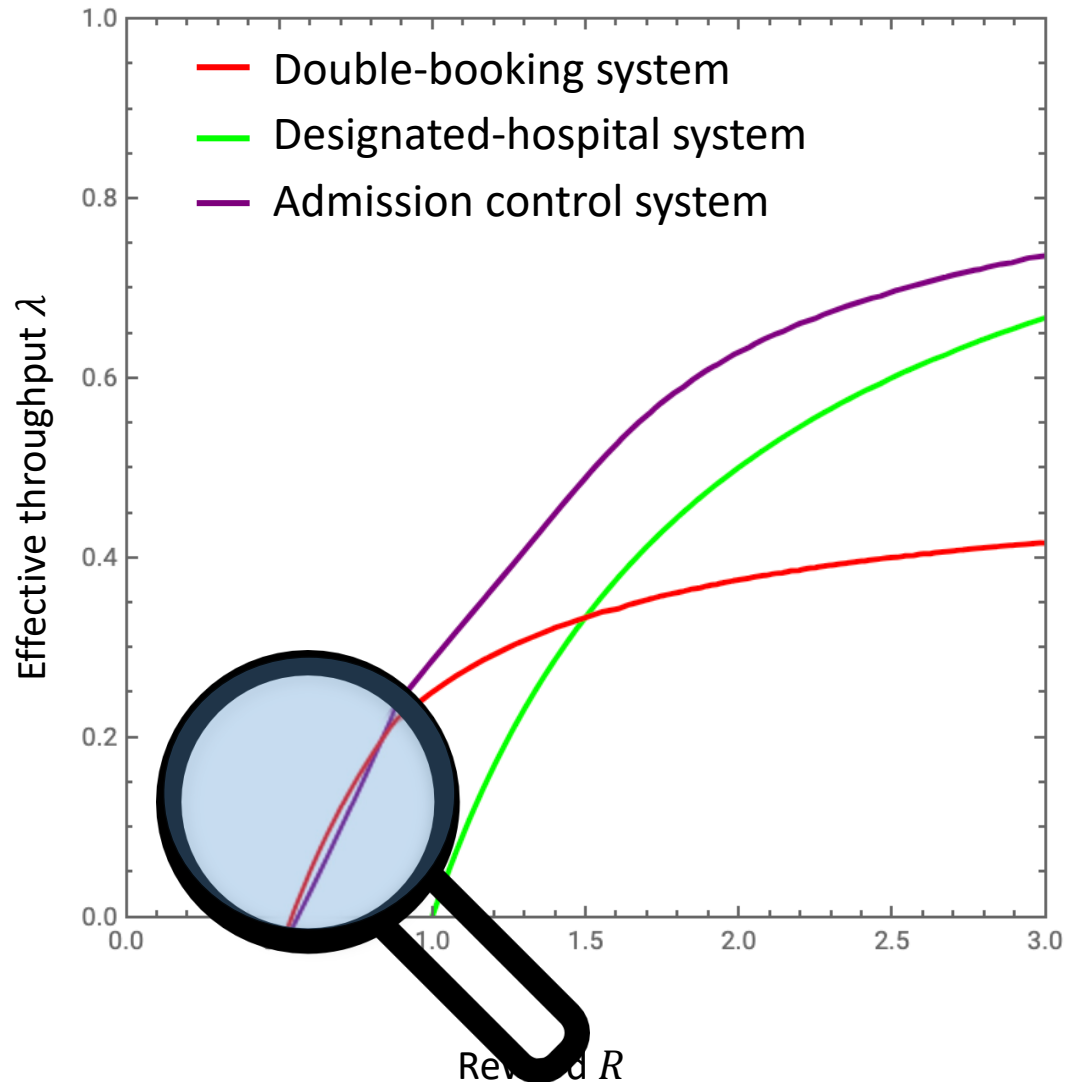

Base Model; low d

Base Model; high d
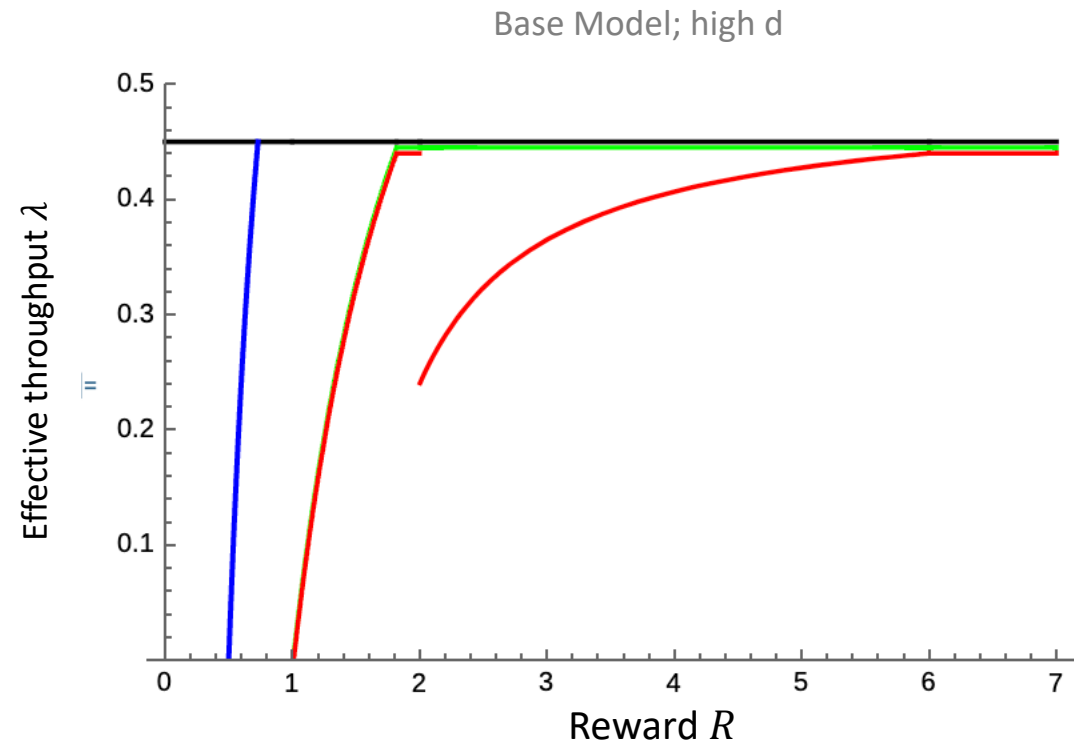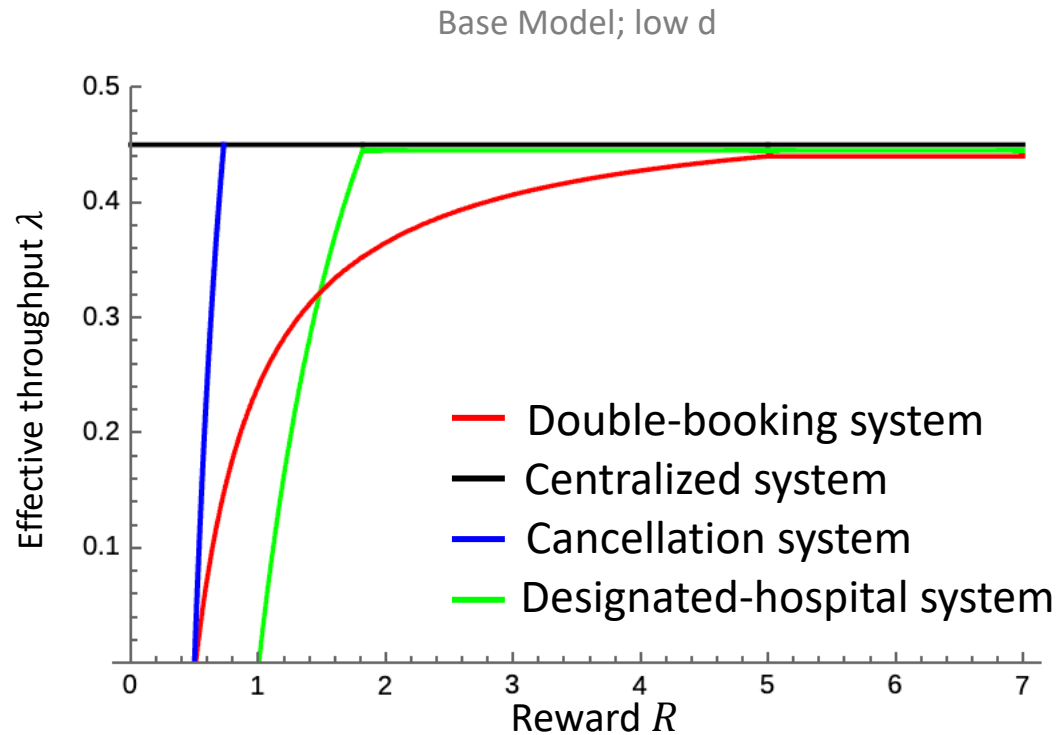
The centralized and cancellation systems are the first two bests, but difficult to implement

Sometimes DB beats the Designated System

Potential solution – Admission control

Base Model; low d

- Locals and non-locals
- Patients call a non-local hospital and are told to try their luck when the hospital is empty

- Admission control is almost always better
- Worst case its performance is within 5% distance from the optimal one

Takeaways & Extensions

Takeaways

- Patient strategic double-booking behavior has a non-trivial effect on system performance
- Natural interventions like more convenient booking system ($d \downarrow$) or promoting the vaccines ($R \uparrow$) may prove detrimental to the system

Extensions & Future Work

- The Neighborhood Case
- Observable model
- Heterogeneous hospitals and/or patients
- Pop-up queues and no-show penalties

Thank you!

arseniy.gorbushin@rotman.utoronto.ca