

# When Are Doctors Most Needed in the Emergency Room: Risk-Adaptive Physician Shift Scheduling

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# Emergency Departments

- ▶ High congestion together with extended waiting time in the Emergency Departments.



Figure 1: ED Waiting Area

# Waiting time

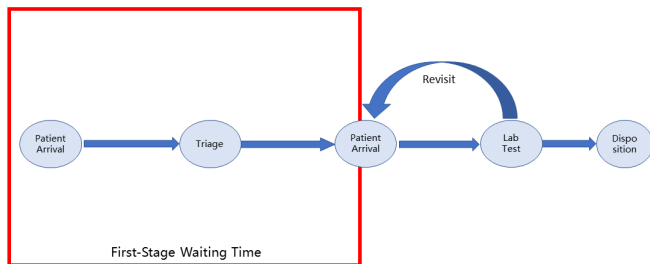


Figure 2: Patients Flow in ED

# Long Waiting time for Patients

	Wait Time <small>What does this show me?</small>	Expected Length of Stay <small>What does this show me?</small>	Status <small>What does this show me?</small>
<b>Vancouver General Hospital</b> <small>Patients of ages 17 and older seen</small>	03:52	04:30 <small>9 times out of 10, you will see a doctor within.</small>	
<b>St. Paul's Hospital</b> <small>Patients of all ages seen</small>	01:52	03:45	
<b>Richmond Hospital</b> <small>Patients of all ages seen</small>	02:07	03:30	
<b>Lions Gate Hospital</b> <small>Patients of all ages seen</small>	02:49	03:45	
<b>Mount Saint Joseph Hospital</b> <small>Patients of all ages seen</small>	01:05	02:45	
<b>UBC Hospital (UBCH)</b> <small>Patients of all ages seen UBCH is for mild to moderate illness</small>	01:03	02:45	
<b>City Centre Urgent &amp; Primary Care Centre</b> <small>Patients of all ages seen UPCC is for mild to moderate illness</small>	00:25	01:15	

Figure 3: A snapshot of the ED waiting time announcement (edwaitingtimes.ca).

# Bottleneck Resources in ED

- ▶ ED bottleneck resources: physicians, beds, etc.
- ▶ The long waiting time has multiple reasons: inefficient staffing schedules, insufficient beds at inpatient unit, etc.

Since we focus on the first-stage waiting time (Time to See MD), we focus on physicians.

## Research Question

How can we adjust physicians' shifts to achieve better outcome?

# ED Waiting Census



Figure 4: The average of waiting census (2018-2019).

# The Current Schedule

SHIFT	FT	PHYSICIAN
0400-0900	0400-0900	S
0700-1400	0900-1400	
0900-1600	1200-1600	
1000-1700	1430-1700	
1200-1900	1630-1900	
1300-2000	1730-2000	
1500-2200	1930-2200	?
1700-2400	2130-2400	
1800-0100	2300-0100	
2130-0400	0100-0400	
2300-0400	2300-0400	

Figure 5: The Intra-day Physician Shift at SPH.



# Demand-Based Scheduling

- ▶ ED administrator sets the physician schedules based on historical arrival data.
- ▶ Congestion-Minimization Way of Thinking.

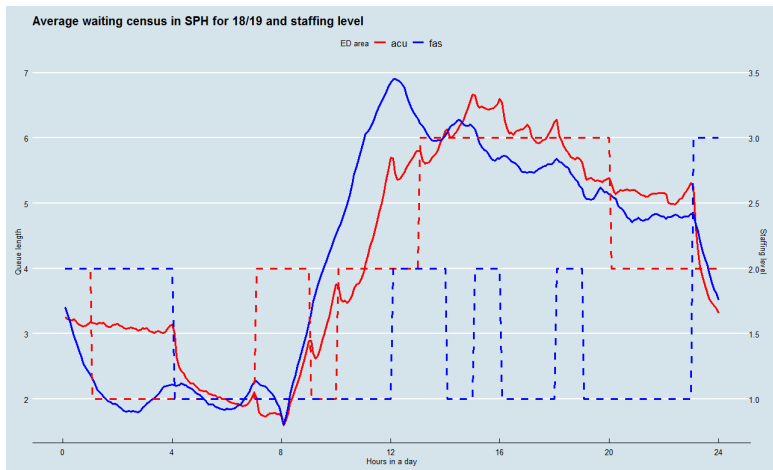


Figure 6: Average waiting census and staffing level at SPH (2018-2019).

# Is Congestion-Minimization the Right Objective?

The underlying assumption for congestion minimization is that the waiting cost is linear in cumulative waiting time and is identical for all patients. However, is this the truth?

## Patient mix

Case 1: three triage-2 patients at 1pm;

Case 2: three triage-3 patients at 4pm.

It is better to set the shift to cover 1pm rather than 4pm.

## Convex waiting cost

Case 1: two triage-2 patients have waited ten and thirty minutes, respectively at 1pm;

Case 2: two patients with the same physical attributes have waited twenty minutes at 4pm.

It is better to cover 1pm rather than 4pm.

# The Waiting Cost is Nonlinear and Patient Specific

- ▶ Most congested period  $\neq$  Most costly period.
- ▶ Cost depends on individual attributes.
- ▶ The cost is convexly increasing in waiting time. (Osuna et al. (1985), Bernstein et al. (2009), Saghafian et al. (2014)).

# Challenges in Measuring the Waiting Cost

- ▶ The “waiting cost” here includes physiological risks as well as the potential social impact and lacks of a clear measurement.
- ▶ Calibrating the comprehensive and integrated waiting cost of patients in the first stage is not easy: short time, not enough data collected. (different from the inpatient unit)

# Our Proposed Method for Measuring Waiting Cost

- ▶ Assumption: physician picks patients for cost minimization.
- ▶ We use physician's decisions to infer the waiting cost of patients in an indirect way, i.e., the **physician-perceived cost** for patients.

# Overview of the Work

- ▶ We first estimate the patients' waiting cost based on a framework.

Ding Y, Park E, Nagarajan M, Grafstein E. Patient prioritization in emergency department triage systems: An empirical study of the canadian triage and acuity scale (CTAS). *Manufacturing & Service Operations Management*. 2019 Oct;21(4):723-41.

- ▶ We then formulate a stochastic optimization to minimize the total waiting cost (estimated) and derive the optimal physician shift.

Ding Y, Jin Y, Hunte G. When are doctors most needed in the emergency department? Risk-adaptive physician shift scheduling. Working paper.

# Literature Review

Based on methodology: three streams of literature on ED operations.

- ▶ **Queueing.** Green et al. (2006), Tezcan et al. (2010), Huang et al. (2015), Baron et al. (2019), Chan et al. (2019), Bijvank et al. (2019), Liu and Sun (2019), Sun et al. (2019), Chen et al. (2019).
- ▶ **Optimization.** Ikegami et al. (2003), Gutjahr et al. (2007), Burke et al. (2014), Saghafian et al. (2015), Liu et al. (2018), He et al. (2019), Rastpour et al. (2020).
- ▶ **Empirical.** Green et al. (2013), Kim et al. (2014), Batt et al. (2017), Baron et al. (2019), Ding et al. (2019).

- ▶ The doctors observe the same information as we researchers do.

POETEST, LISA ...

Tracking List

ED Doctor | ED All Beds | ED Available Staff | ED Look Up | ED Pending Lab | ED Doctor | ED All Beds | ED Available Staff | ED Look Up | ED Pending Lab | ED Doctor | ED All Beds

Patient: CPOETEST, LISA ONE | WR: 7 | Total: 20 | Avg LOS: 601:32 | Filter: My Patients and Unassign

Bed	CS	VI	A Name	Age	Reason for Visit	Comment	LOS	EP	MLP	RN	Sign	ECG	La
05,A			2 LABTEST, TWO	34 y			59:10	Brown				2/0	12
06,A			3 RODRIGUEZ, SHAE	31 y	1: Intentional dru		31:24			Dana			
★ 07,A			1 LABTEST, THREE	35 y	1: Altered mental ct done		85:20					4/0	9/8
09,A			M32,		1: MVC		69:52						
10,A			TEST, VIDEO	57 y			69:52						1/0
11,A			4 TEST, DANA	35 y	1: Potential strok		00:20		Smith	shae			
14,A			TEST, FLOWSHEET	37 y			69:49						
15,A			2 TEST, TIRED	85 y	1: Chest pain		78:09			Dana			
16,A			5 TRAIN, TECH	30 y	1: Abdominal pai		88:13						1/0
17,A			COVENTRY, EIGHT	45 y			01:36		Smith	Dana			
30,A			TEST, STATUSORDI	65 y			25:40						
★ OF1,A			3 LABTEST, ONE	35 y	1: Abdominal pai		85:20	Brown				1/0	7/6
PA			M24,		1: Chest pain		69:55						
WR			VCREGCLERK, CER	26 y			66:26						
WR			4 TUESDAY, JUDY	27 y	1: Wrist injury - M		64:10			Shae			
WR			ASC, TRAIN	30 y			63:44						
WR			PTACCESS, AUTH	39 y			58:59						
WR			TEST, EFORMS	41 y			65:38						
WR			3 CPOETEST, LISA ON	59 y	1: Psychiatric pri		0:40						
WR			3 TESTFN, BOB	69 y	1: Abdominal pai		44:27	Brown					

Figure 7: A snapshot of the Patient Care Information System (PCIS).



# Estimated Marginal Waiting Cost Function

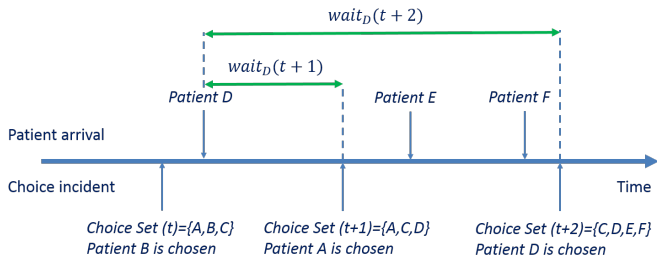
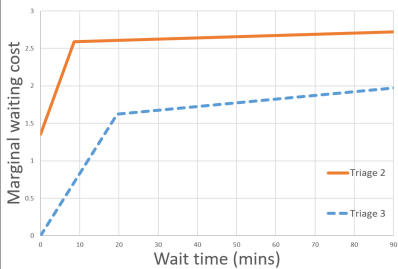


Figure 8: An approximate diagram of the estimated MWC

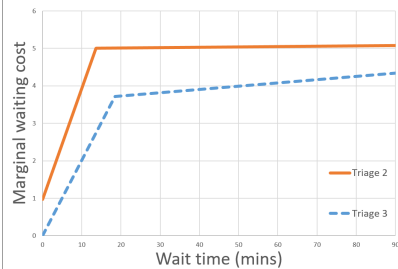
# Available Dataset

- ▶ The data is at the patient visit level where each observation corresponds to a single patient visit to the ED.
- ▶ 1.2 million observations and 121 variables from April 2016 till March 2019 (fiscal year).
- ▶ Covers 6 major EDs in Metro Vancouver.

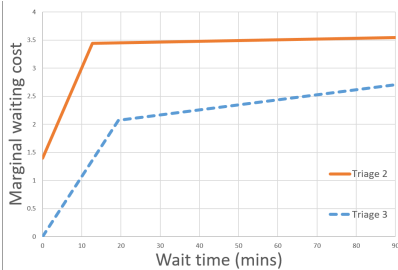
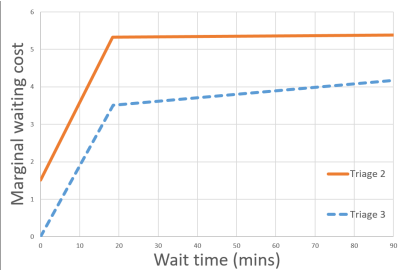
# Estimated Marginal Waiting Cost



(a) ED A



(b) ED B



# CTAS Fractile Response Objective

CTAS score	Triage	Target	Fractile
1	Resuscitation	Immediately	98%
2	Emergent	15 minutes	95%
3	Urgent	30 minutes	90%
4	Less urgent	60 minutes	85%
5	Non-urgent	120 minutes	80%

# The Physician-Demand Index

- ▶ Using the estimated patient cost, we can infer which period is most costly.
- ▶ **Interpretation:** The index represents the reduction in the total waiting cost by adding one additional physician pick at certain time of a day.
- ▶ We search for the optimal shift adjustment using the *physician-demand* index.

## Index Formulation

$$\text{Index}(t) \equiv \int_t^{\gamma(t)} \max_{i \in \text{Choiceset}(s)} C'_i(s) ds, \quad \gamma(t) = \inf\{s | s \geq t, Q(s) = 0\},$$

# Index Computation Results

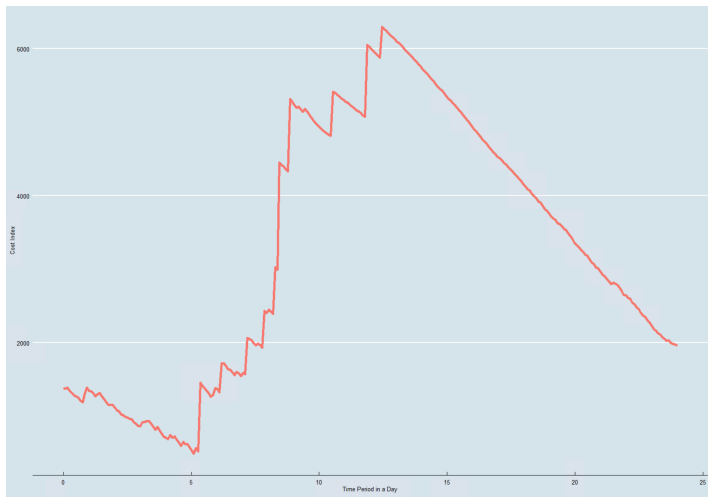


Figure 10: The average index of two weeks along one day.

# Adjusting Current Staffing Schedules

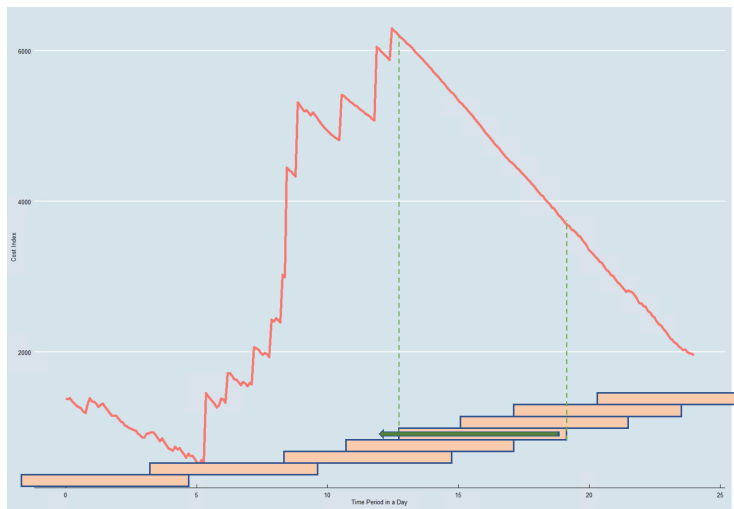


Figure 11: Likely change of the current staffing schedules.

# Adjusting Current Staffing Schedules

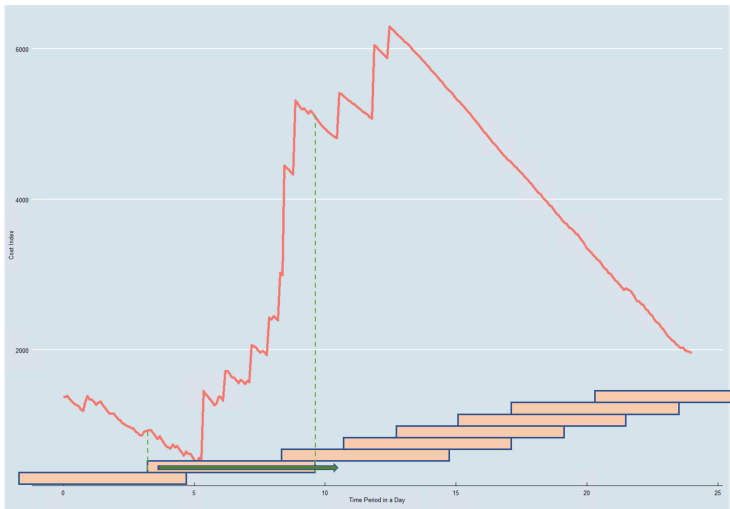


Figure 12: Likely change of the current staffing schedules.



# Future Directions

- ▶ Robust check for the model by considering seasonality, physician heterogeneity
- ▶ Running simulations to compare the performance of the index policy, an ad hoc policy and the current policy.
- ▶ We plan for implementation at our collaborating hospital.

THANK YOU !