

# Forecasting of Staffing Needs

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# Agenda

- Introduction
- The Analysis
  - Predicted Number of Exceptions
  - Predicted Number of Urgent Exception Groups
  - Exceptions Classification
- The Dashboard

# Introduction

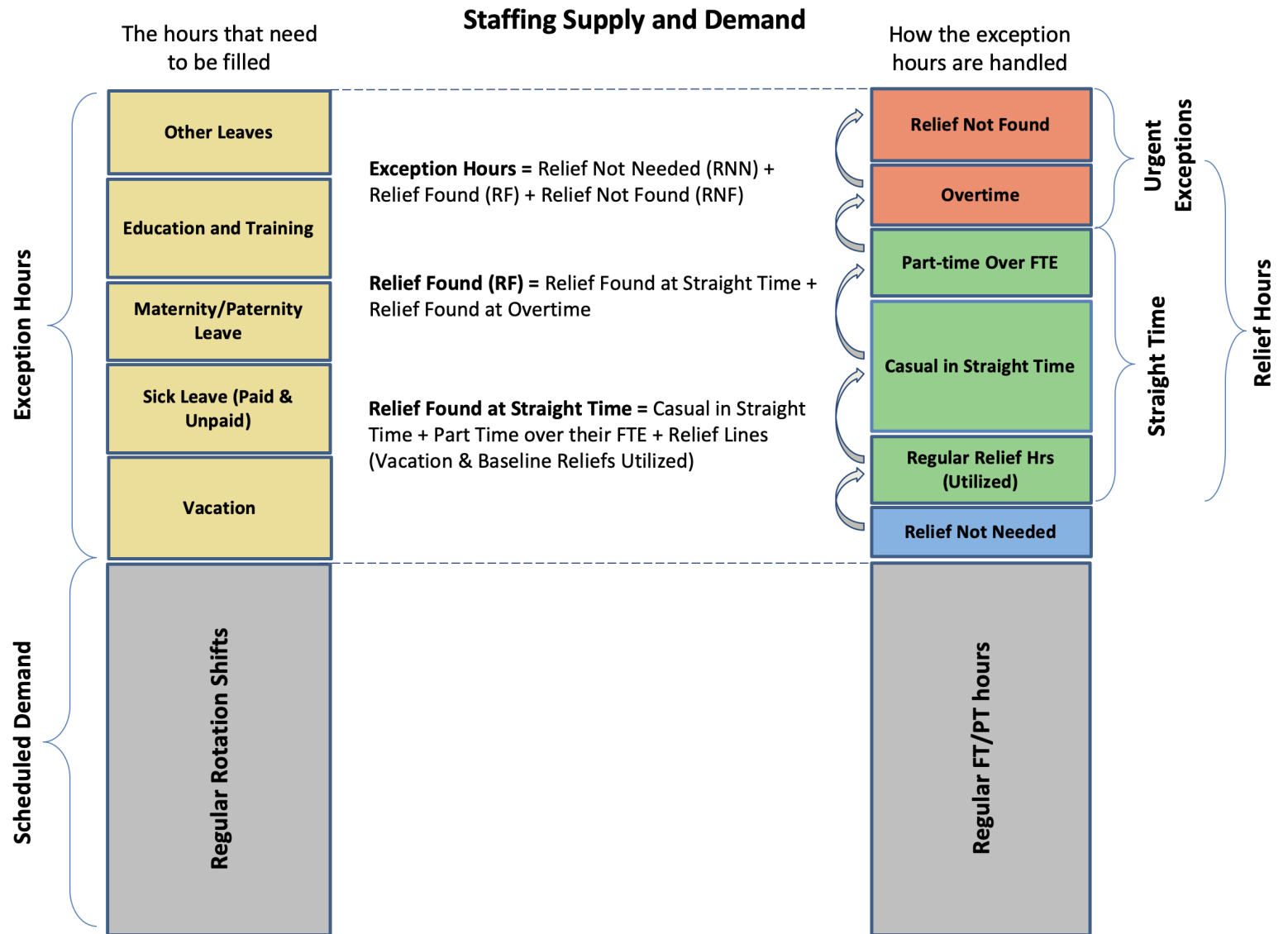
## The Partner - Providence Health Care

- Providence Health Care (PHC) is a non-profit organization.
- Almost 9,000 people working at their 16 facilities - 6,000 staff, 1,000 medical staff/physicians, 200 researchers, 1,600 volunteers.
- PHC is the provincial centre for the care of six groups of people with often-intensive health needs.



## The Problem

- In the healthcare business, staff absences must always be backfilled.
- These absences, expected or not, are called **exceptions**.
- One way to minimize their impact is to predict future exceptions based on historical data.



## Objective

The purpose of this project was to predict the short-term staff needs in order to provide PHC some insight into unexpected potential costs and staff shortages.

Specifically we focused on building models for:

- Forecasting staffing needs on a weekly basis, allowing PHC to estimate how many back up staff are needed;
- Forecasting how many exceptions will fall under the urgent exception groups (i.e. overtime and relief not found);
- Forecasting possible outcome for each exceptions submitted.

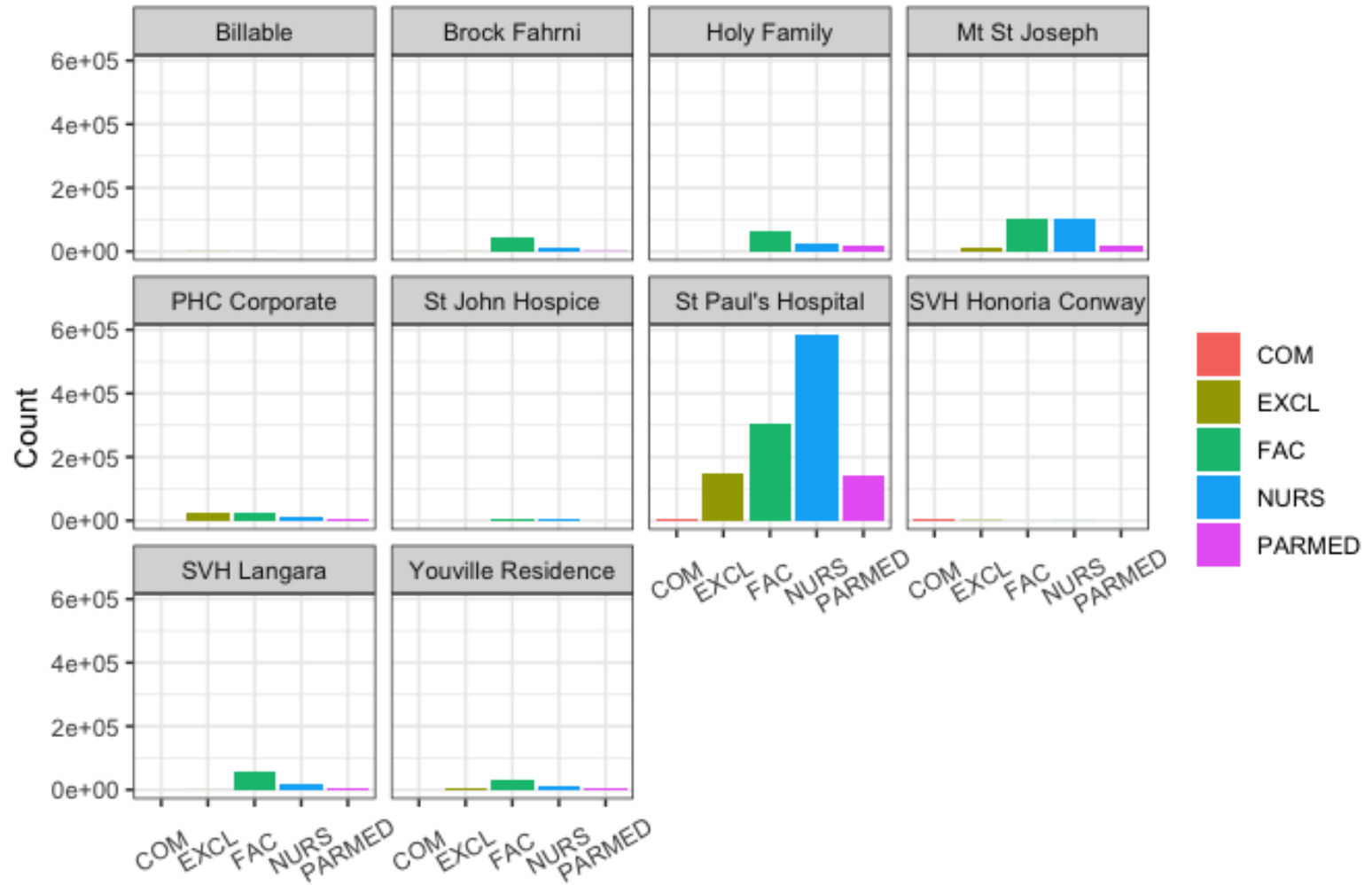
## **The Analysis**



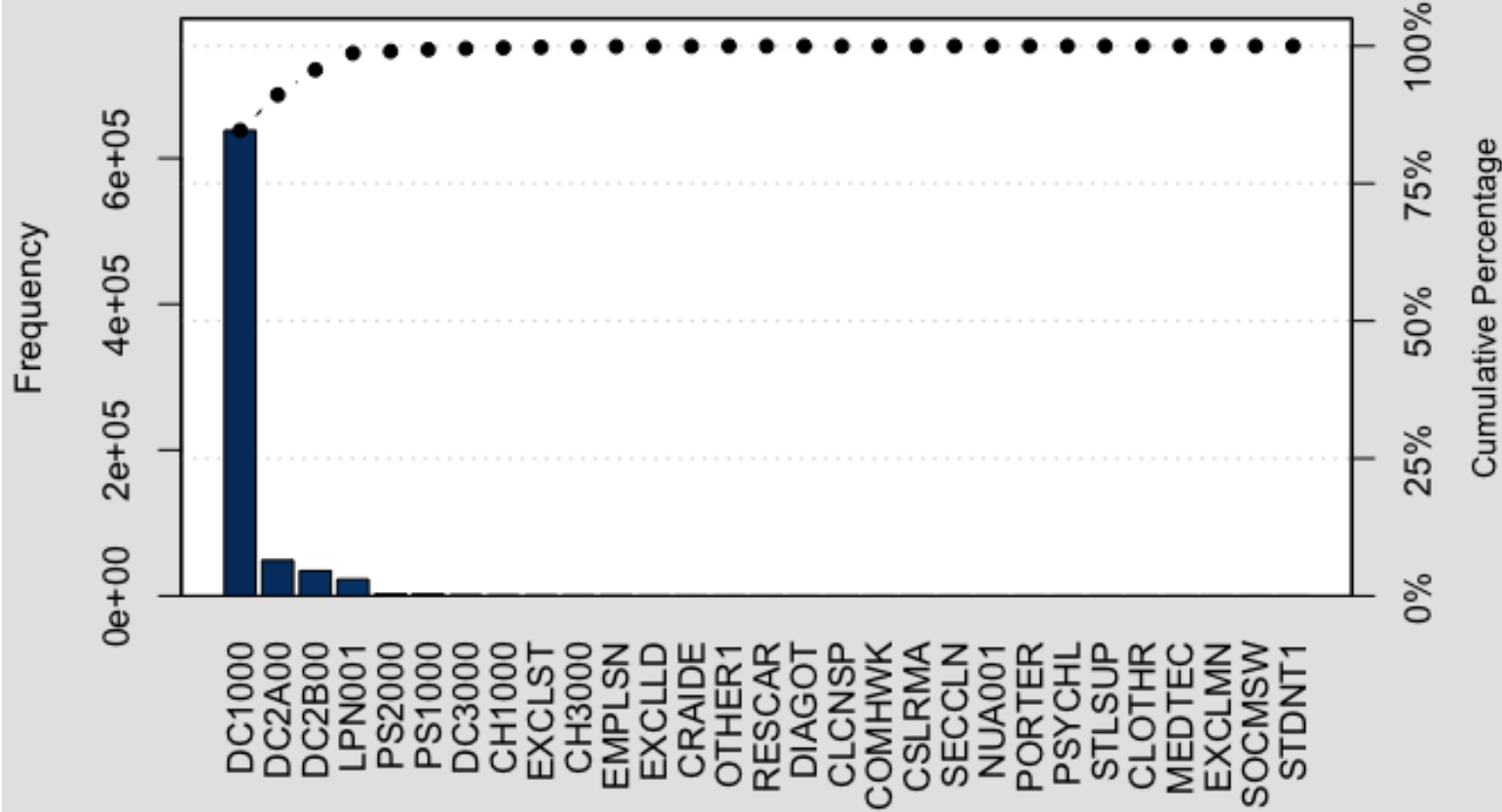
We performed an EDA to indentify the facilities, labour agreement and job families we should focus on.

```
## # A tibble: 10 x 2
##   SITE                count
##   <chr>              <int>
## 1 St Paul's Hospital 420961
## 2 Mt St Joseph      83590
## 3 Holy Family        37197
## 4 SVH Langara        29193
## 5 PHC Corporate      24002
## 6 Brock Fahrni       19530
## 7 Youville Residence 15678
## 8 SVH Honoria Conway  2799
## 9 St John Hospice    2154
## 10 Billable          555
```

# Number of Exceptions by Labor Agreement per Site (2013 - 2017)



Pareto of Exceptions per NURS Job Families



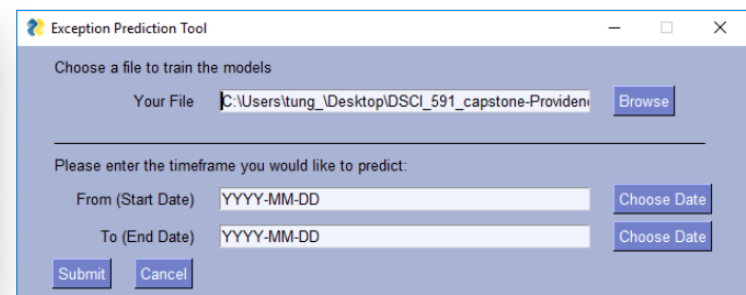
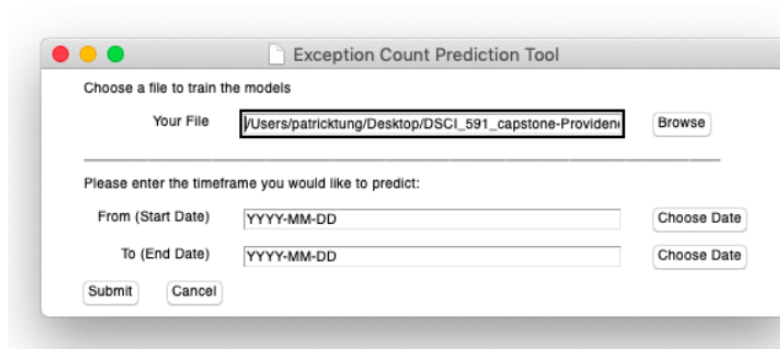
# Exception Count Prediction

Forecasting the number of exceptions for Providence Health Care

## Method

- Data
  - Training: 2013 - 2016
  - Validation: 2017
  - Testing: 2018
- Data Wrangling
  - Split data by SITE, JOB\_FAMILY, and SUB\_PROGRAM
  - e.g. St Paul's Hospital, Registered Nurse - DC1, Emergency
- Fit time series model for each “combination”
  - Facebook Prophet
- Predict the number of exceptions for the combinations
- Adjusted models based on Mean Absolute Error
- Output a .csv file containing the forecasts

## Product/Interface



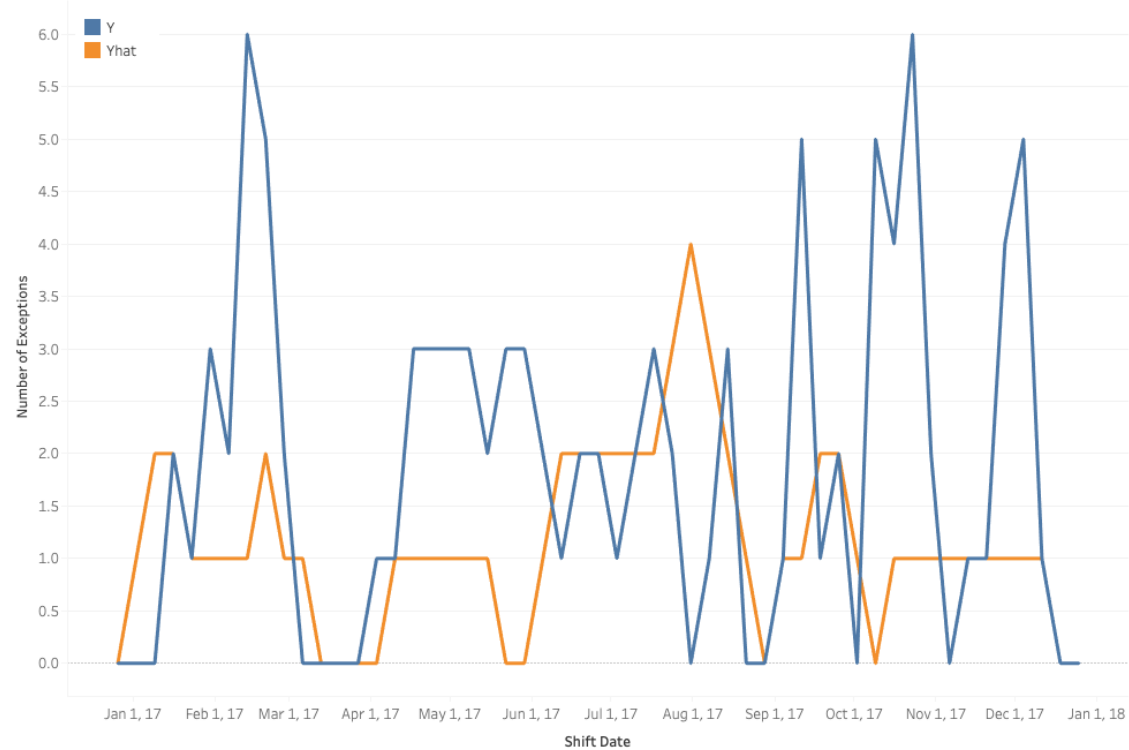
## Output file

- .csv file containing all the predictions (on a weekly basis)

	A	B	C	D	E	F	G	H	I
1		yhat	yhat_lower	yhat_upper	ds	week	site	job_family	sub_program
2	0	8	0	19	12/31/18	1	St Paul's Hos	DC2B00	RENAL 6AB
3	1	6	0	18	12/31/18	1	St Paul's Hos	DC2B00	RENAL 6AB
4	2	5	0	17	12/31/18	1	St Paul's Hos	DC2B00	RENAL 6AB
5	3	5	0	16	12/31/18	1	St Paul's Hos	DC2B00	RENAL 6AB
6	4	5	0	16	12/31/18	1	St Paul's Hos	DC2B00	RENAL 6AB
7	5	5	0	16	12/31/18	1	St Paul's Hos	DC2B00	RENAL 6AB
8	6	4	0	16	12/31/18	1	St Paul's Hos	DC2B00	RENAL 6AB
9	7	4	0	15	1/7/19	2	St Paul's Hos	DC2B00	RENAL 6AB
10	8	4	0	16	1/7/19	2	St Paul's Hos	DC2B00	RENAL 6AB
11	9	5	0	16	1/7/19	2	St Paul's Hos	DC2B00	RENAL 6AB
12	10	7	0	18	1/7/19	2	St Paul's Hos	DC2B00	RENAL 6AB
13	11	7	0	19	1/7/19	2	St Paul's Hos	DC2B00	RENAL 6AB
14	12	7	0	19	1/7/19	2	St Paul's Hos	DC2B00	RENAL 6AB
15	13	7	0	19	1/7/19	2	St Paul's Hos	DC2B00	RENAL 6AB
16	14	7	0	18	1/14/19	3	St Paul's Hos	DC2B00	RENAL 6AB
17	15	7	0	18	1/14/19	3	St Paul's Hos	DC2B00	RENAL 6AB
18	16	7	0	18	1/14/19	3	St Paul's Hos	DC2B00	RENAL 6AB
19	17	6	0	17	1/14/19	3	St Paul's Hos	DC2B00	RENAL 6AB
20	18	5	0	17	1/14/19	3	St Paul's Hos	DC2B00	RENAL 6AB
21	19	5	0	16	1/14/19	3	St Paul's Hos	DC2B00	RENAL 6AB
22	20	5	0	17	1/14/19	3	St Paul's Hos	DC2B00	RENAL 6AB

## Difficulties

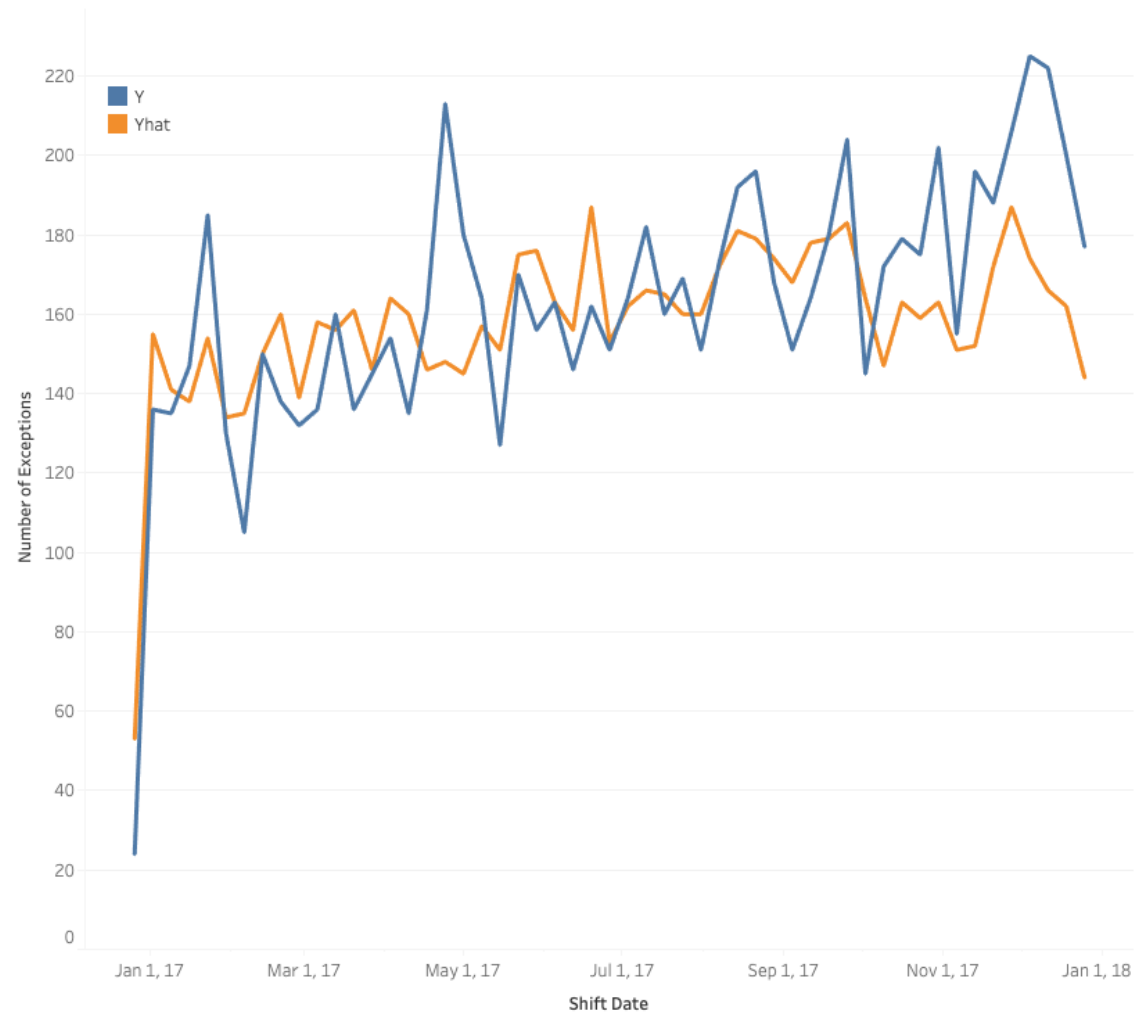
- Certain combinations of data had very little exceptions
  - Little to no pattern
  - Predictions are not meaningful
- e.g. Youville Residence, Registered Nurse - DC2B - Parkview





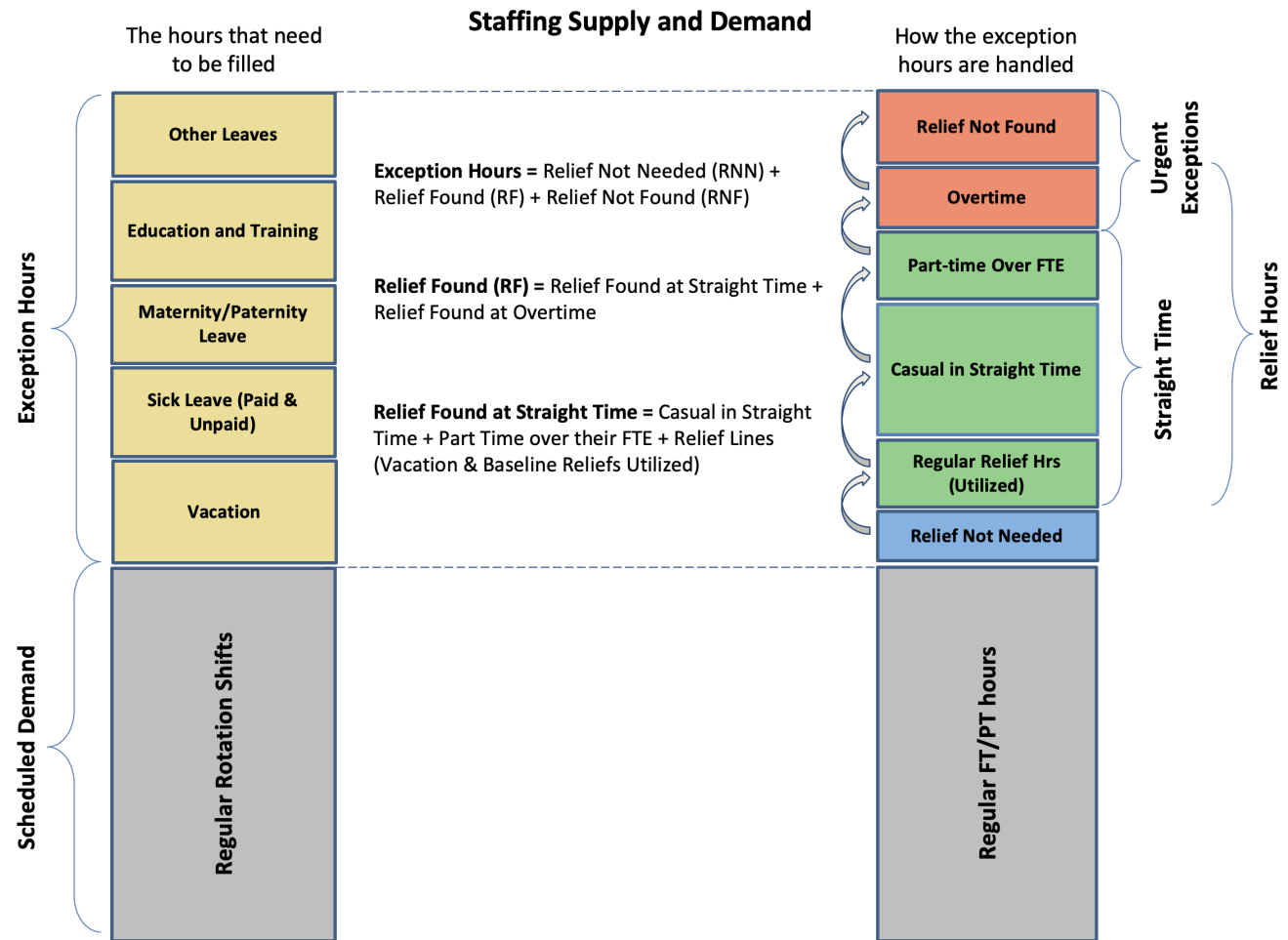
## Solution

- Fit meaningful data using a threshold
  - Must have 300 exceptions within the past 4 years
- e.g. St Paul's Hospital, Registered Nurse - DC1, EMERG
  - MAE: 55.22



# **Urgent Exception Prediction**

Predicting the number of urgent exceptions



## Urgent Exception

- Exceptions backfilled by **Overtime** and **Relief Not Found**
  - Overtime: high cost that need to minimize
  - Relief Not Found: need to avoid
- Give a insight so HR can arrange on-call and other backfills

## Method

- Linear Regression

## Data

- Dates: Until 2018, excluding 2014
- Job Family: DC1000, DC2A00, DC2B00
- Earning Category: Overtime & Relief Not Found

## Difficulties

- Low correlation
- Randomness in daily basis



## Variables

- Dates (One Hot Encoding)
  - Day of week, day of month, week of year, month of year
- Productive hours

## Input file

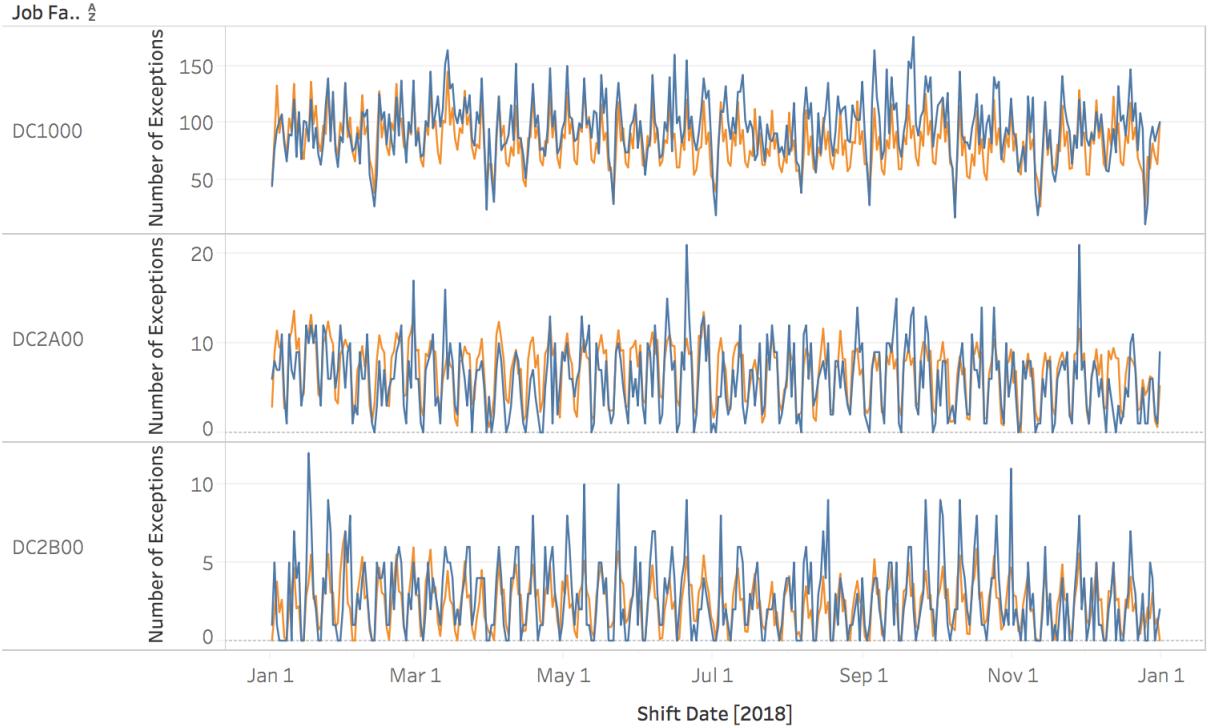
- Exception Hours for past years
- Productive Hours for past years
- Productive Hours for the period you want to predict (estimation)

## Output file

- .csv file with dates, job family, predicted count

	A	B	C	D
1		yhat	ds	job_family
2	0	46.5760008	1/1/18	DC1000
3	1	86.868815	1/2/18	DC1000
4	2	133.55888	1/3/18	DC1000
5	3	91.3956964	1/4/18	DC1000
6	4	106.572805	1/5/18	DC1000
7	5	85.9658619	1/6/18	DC1000
8	6	72.0211963	1/7/18	DC1000
9	7	104.243195	1/8/18	DC1000

Actual vs. Predictions per Job Family



Shift Date

1/1/2018 12/31/2018

Actual Values

Predictions

## **Exception Classification**

Forecasting possible outcome for each exception submitted

## Label Grouping

- EARNING\_CATEGORY is the final outcome for an exception
- Original EARNING\_CATEGORY has 12 values which is too much for classification
- 3 labels is more reasonable for classification:
  - Straight Time: Regular Relief Utilized, Casual at Straight-Time, PT Over FTE, Miscellaneous Straight-Time, PT Employee Moved - Straight-Time, FT Employee Moved - Straight-Time
  - Overtime and Beyond: Overtime, Agency, Insufficient Notice, On-Call, Relief Not Found
  - Relief Not Needed: Relief Not Needed.

## Feature Selection

- Using EXCEPTION\_HOURS, EXCEPTION\_CREATION\_TO\_SHIFTSTART\_MINUTES, NOTICE as accuracy baseline.
- Using forward selection, adding SITE, PROGRAM, SUB\_PROGRAM, EXCEPTION\_GROUP, MONTH, DEPARTMENT, SHIFT.

## Prediction Result Analysis

Validation Accuracy	0.841
Straight Time Accuracy	0.936
Overtime and Beyond Accuracy	0.638
Relief Not Needed Accuracy	0.308



## Difficulties

- Imbalanced Data

	Training Data Set
Number of Straight Time	262,608
Number of Overtime and Beyond	76,863
Number of Relief Not Needed	11,086

## Accuracies

	Validation Accuracy		Test Accuracy
	Original Model	Adjusted Model	
<b>Overall</b>	0.841	0.794	0.800
<b>Straight Time</b>	0.936	0.823	0.830
<b>Overtime &amp; Beyond</b>	0.638	0.735	0.756
<b>Relief Not Needed</b>	0.308	0.625	0.633

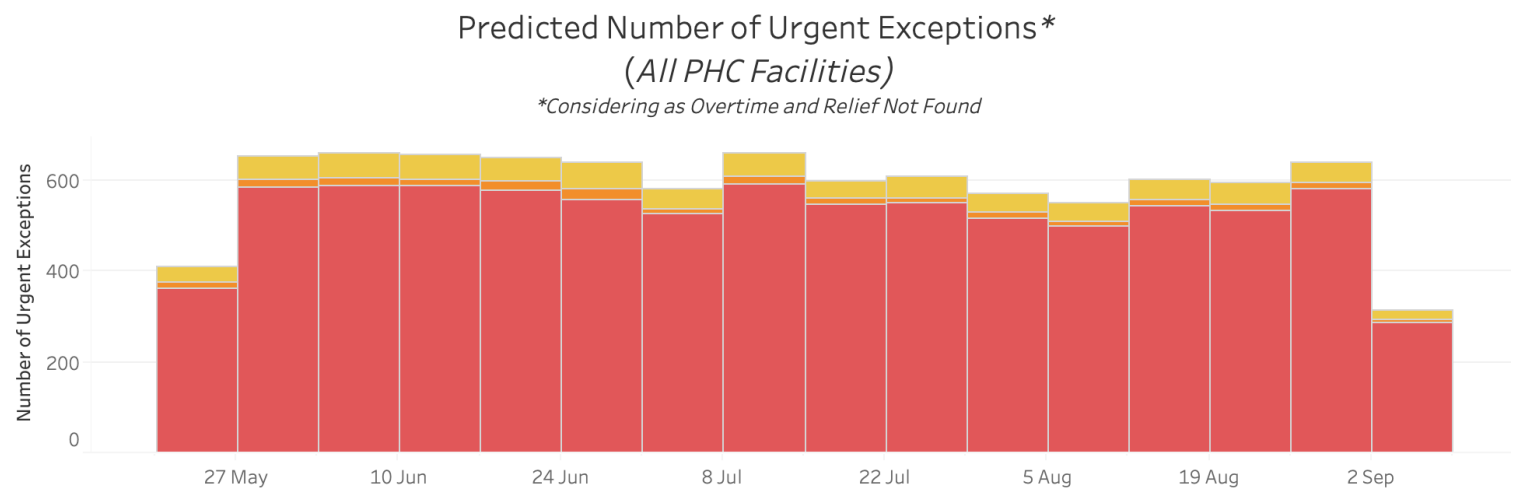
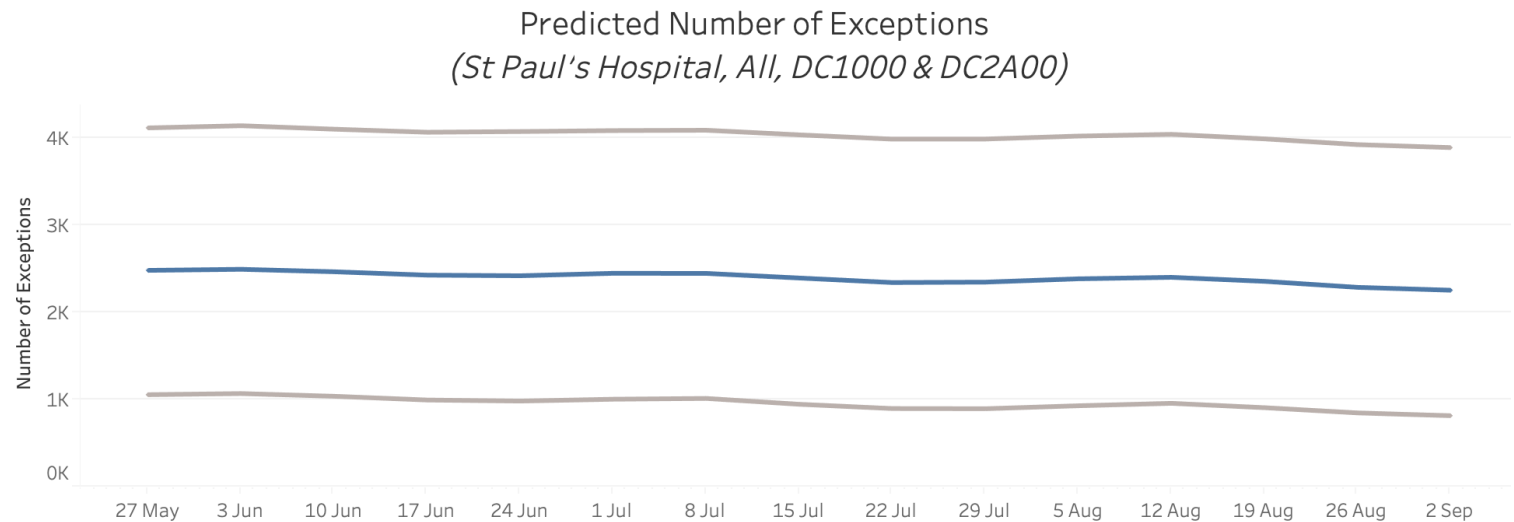
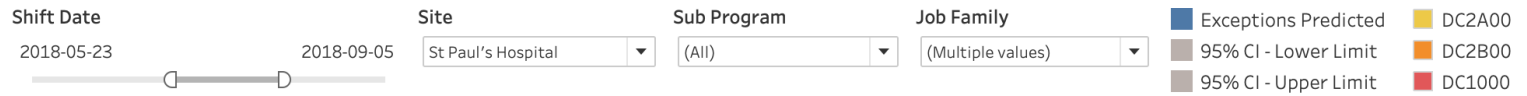
## Output file

- .csv file with the prediction result

	AX	AY
1	SHIFT_	PREDICTION
2	1	Straight Time
3	1	Overtime and Beyond
4	2	Straight Time
5	3	Straight Time
6	1	Straight Time
7	1	Straight Time
8	1	Straight Time
9	2	Overtime and Beyond
10	1	Overtime and Beyond
11	3	Straight Time
12	1	Overtime and Beyond

# Dashboard

# Exception Predictions



# Exceptions Classification

Exceptions Classification					Shift Date	
Month of Shift Date	Site	Overtime and Beyond	Relief Not Needed	Straight Time	2018-06-06	2018-12-31
June	Brock Fahrni	24		43		
	Holy Family	88	14	226		
	Mt St Joseph	324	41	523		
	St Paul's Hospital	1,669	318	3,490		
	SVH Langara	36	1	137		
	Youville Residence	16	1	73		
July	Brock Fahrni	21		72		
	Holy Family	75	4	265		
	Mt St Joseph	555	65	770		
	St Paul's Hospital	1,480	327	4,371		
	SVH Langara	47	3	180		
	Youville Residence	34	9	74		
August	Brock Fahrni	31		62		
	Holy Family	91	2	266		
	Mt St Joseph	367	108	832		
	St Paul's Hospital	1,801	397	4,754		
	SVH Langara	21		194		
	Youville Residence	15	1	87		
September	Brock Fahrni	16		75		
	Holy Family	99		209		
	Mt St Joseph	317	85	633		
	St Paul's Hospital	1,943	308	4,183		
	SVH Langara	26		114		
	Youville Residence	21	10	98		
October	Brock Fahrni	24		89		
	Holy Family	89	1	185		
	Mt St Joseph	311	65	619		
	St Paul's Hospital	1,976	380	4,244		
	SVH Langara	34	4	134		
	Youville Residence	15		58		
November	Brock Fahrni	14		69		
	Holy Family	97		239		
	Mt St Joseph	304	55	567		

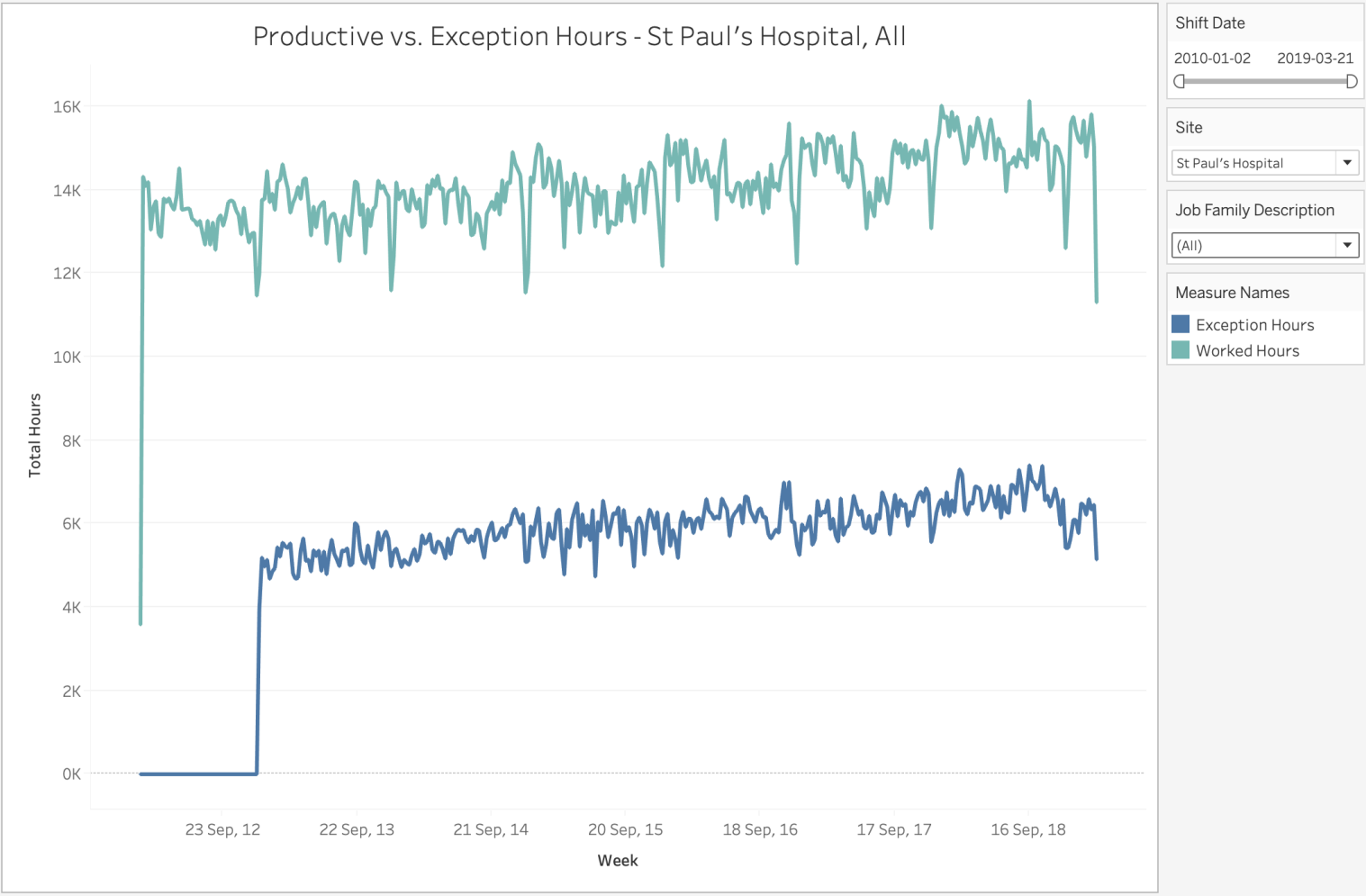
Shift Date

2018-06-06 2018-12-31

Site

- ☒ (All)
- ☒ Brock Fahrni
- ☒ Holy Family
- ☒ Mt St Joseph
- ☒ St Paul's Hospital
- ☒ SVH Langara
- ☒ Youville Residence

# Comparison of Productive and Exception Hours



## Summary

- Data product contains the three models
- Results from the models can be shown in tableau dashboard
- HR can choose models based on the data they get
- Provide insights from the predictions to help decision making



**Thank you!**