

Forecasting of Staffing Needs in Health Care

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Agenda

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

Introduction

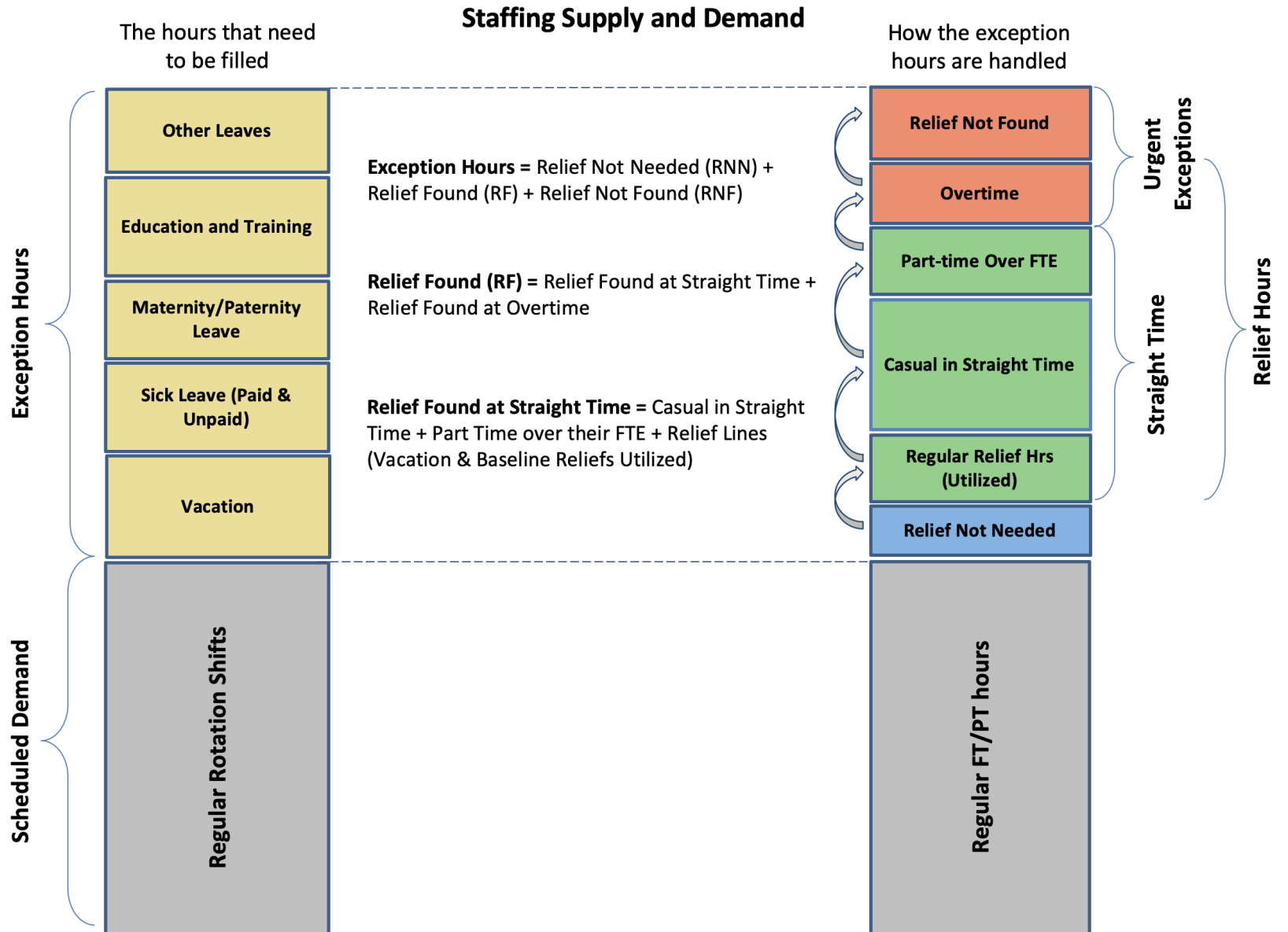
The Partner - Providence Health Care

- 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

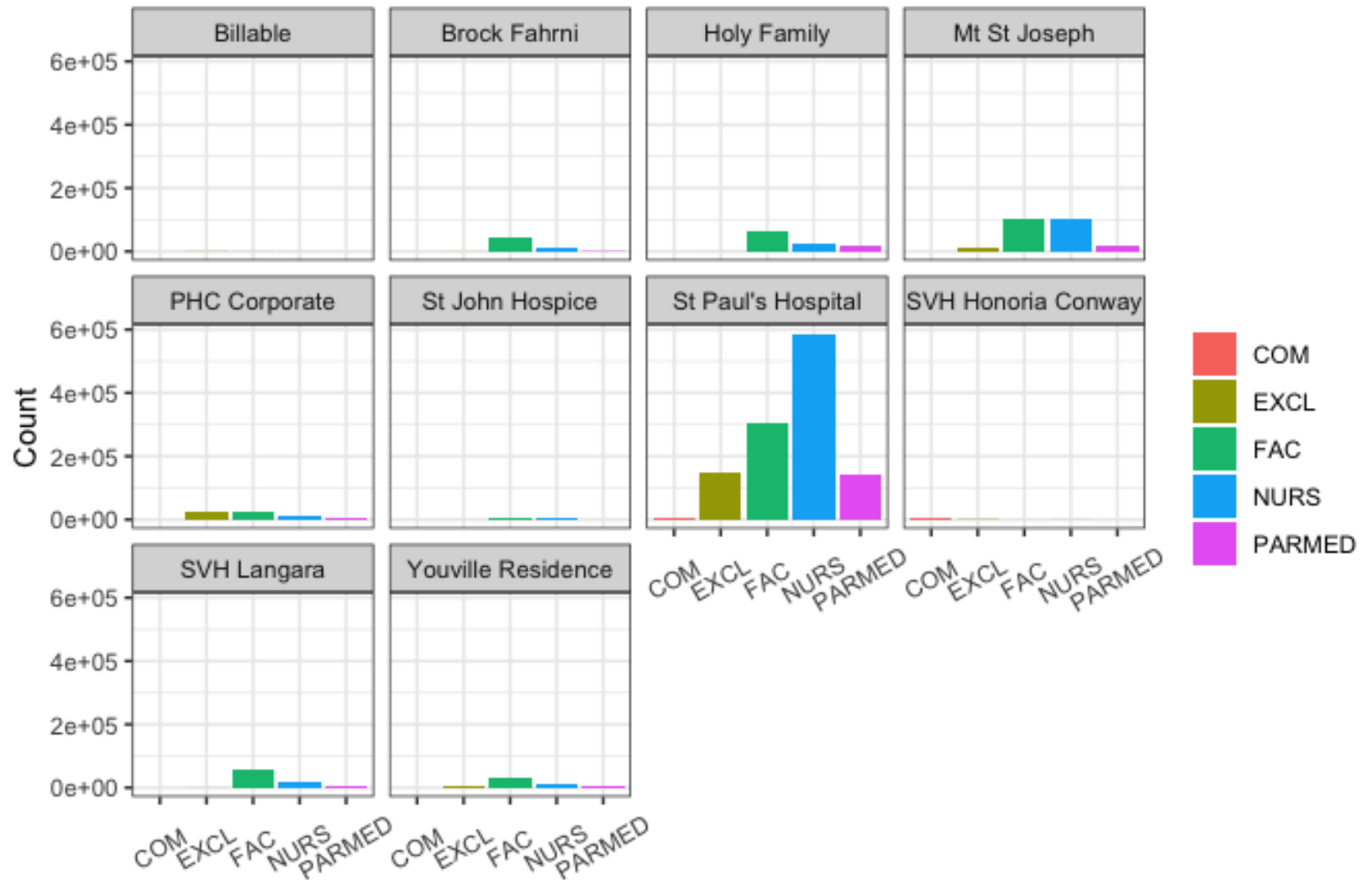
EDA

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

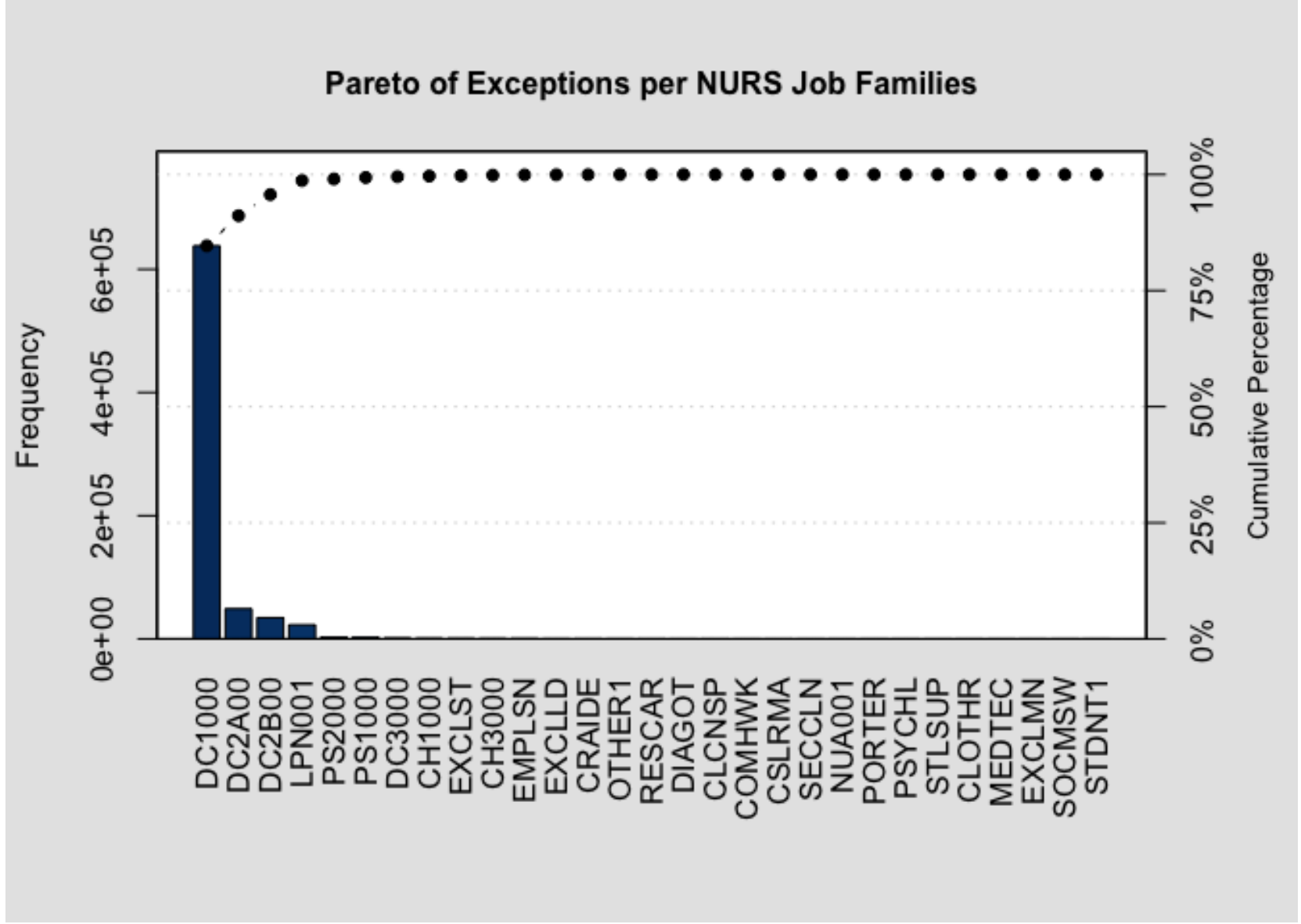
```
## # A tibble: 10 x 2
##   SITE                                count
##   <chr>                             <int>
## 1 St Paul's Hospital 420961
## 2 Mt St Joseph      83590
## 3 Holy Family        37197
## 4 SVH Langara        29193
## 5 PHC Corporate      24002
## 6 Brock Fahrni       19530
##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

EDA

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



EDA



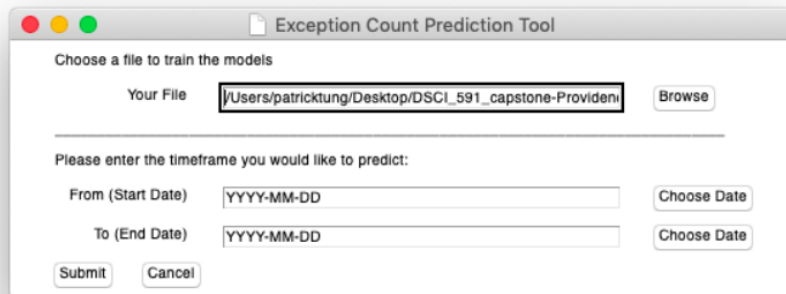
Exception Count Prediction

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



Exception Count Prediction Tool

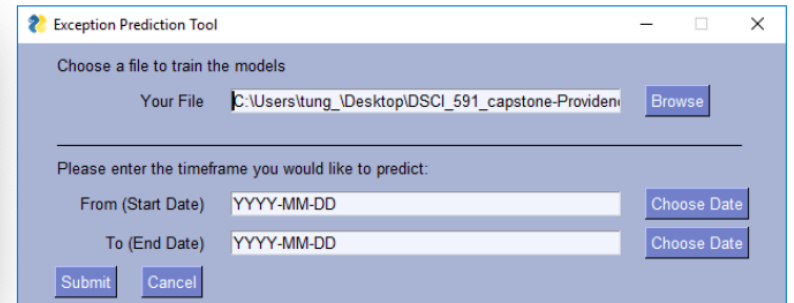
Choose a file to train the models

Your File

Please enter the timeframe you would like to predict:

From (Start Date)

To (End Date)



Exception Prediction Tool

Choose a file to train the models

Your File

Please enter the timeframe you would like to predict:

From (Start Date)

To (End Date)

Output file

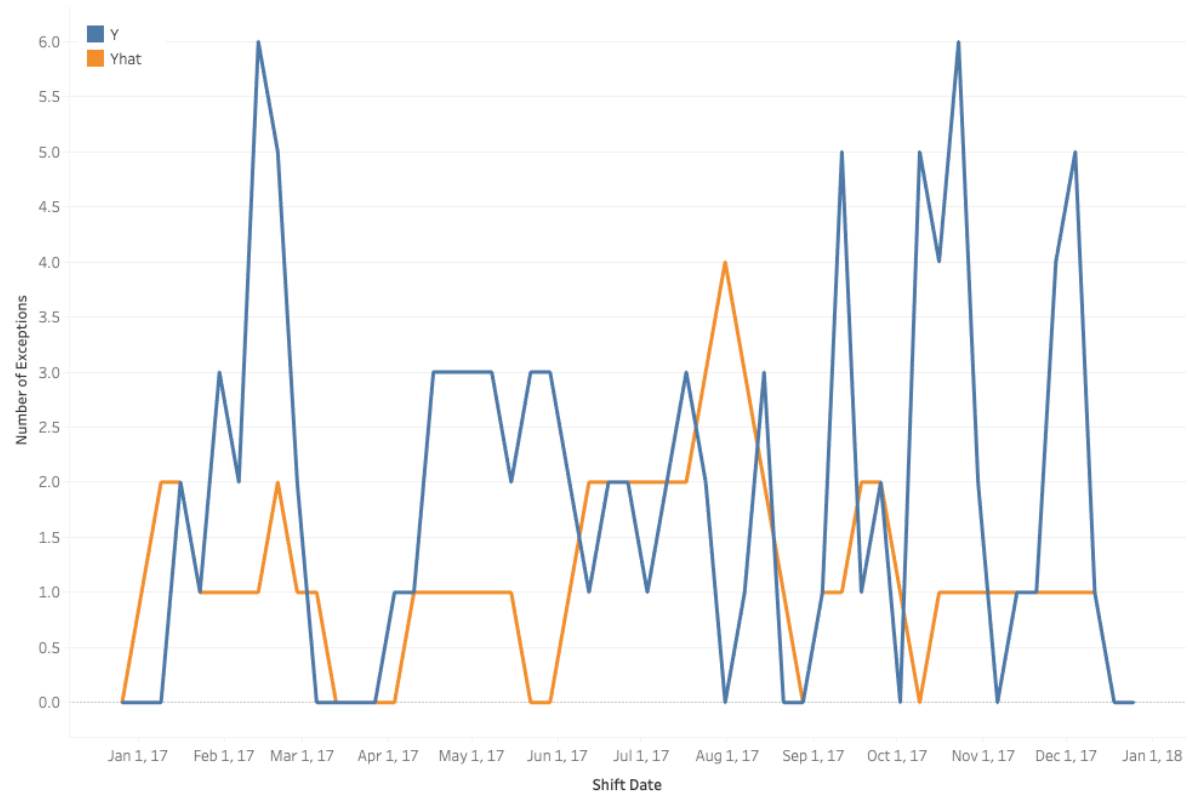
- .csv file containing all the predictions (on a weekly basis)

	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

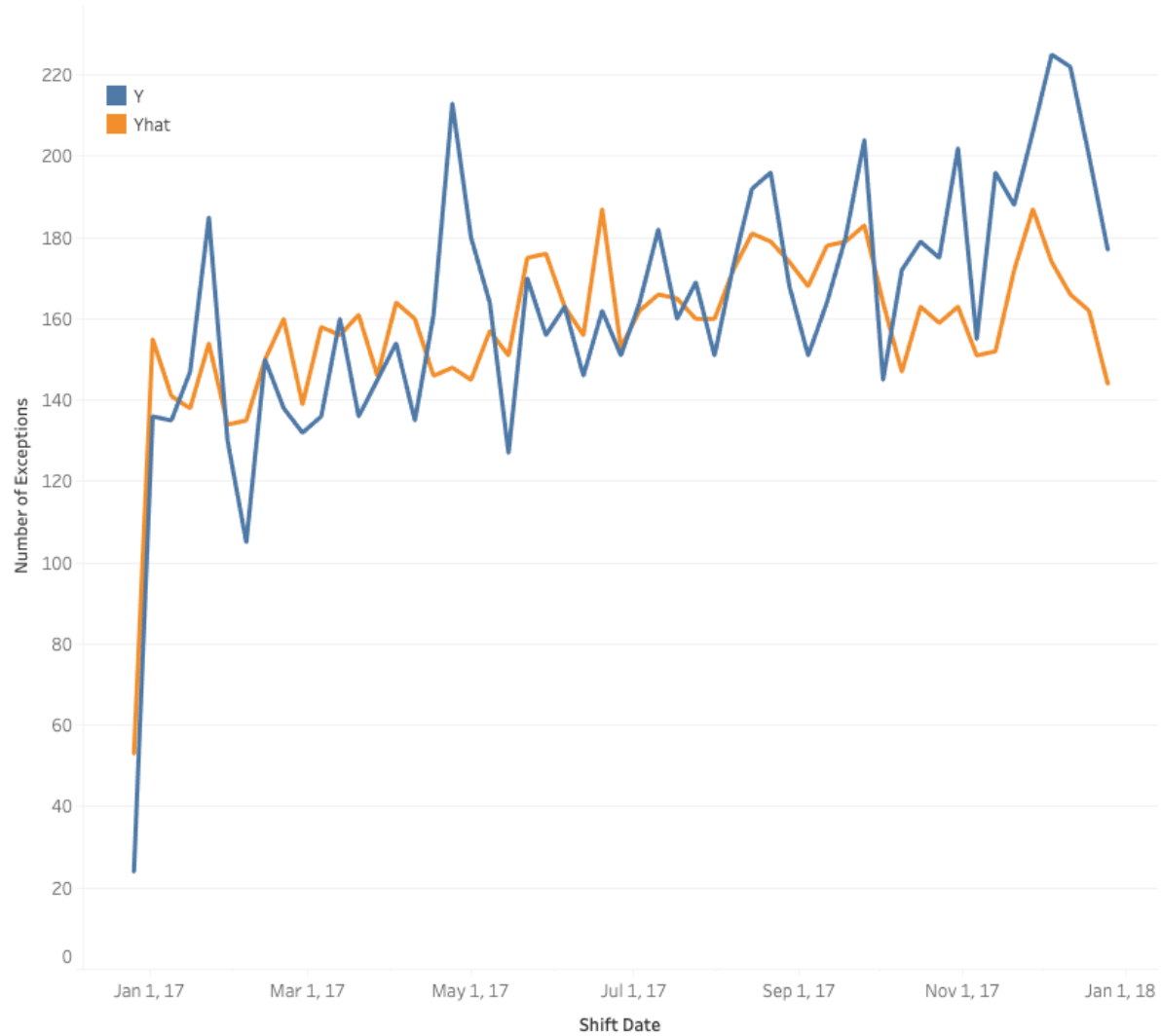
- e.g. Youville Residence, Registered Nurse - DC2B - Parkview



Solution

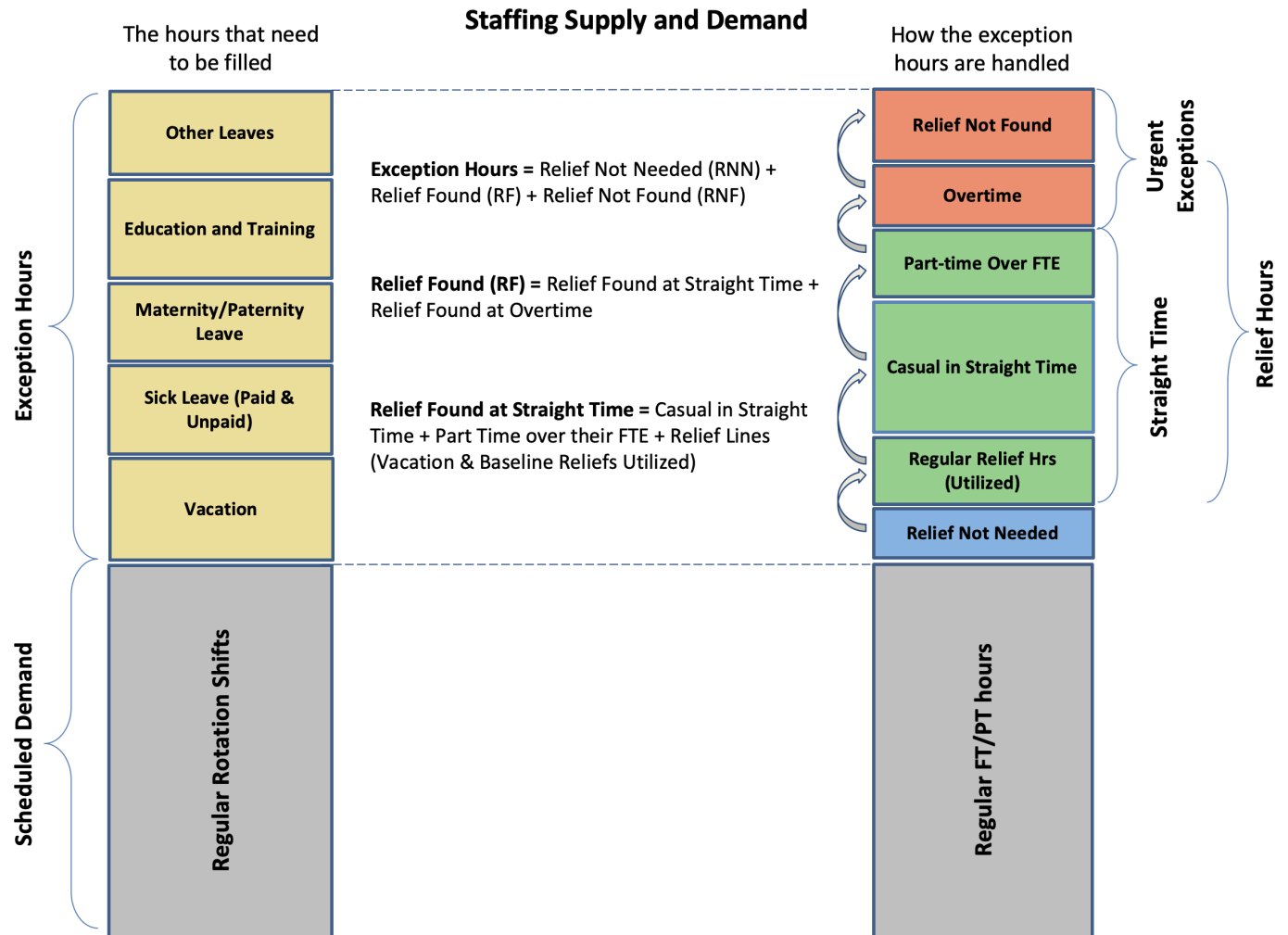
- Fit meaningful data using a threshold
 - Must have 300 exceptions within the past 4 years

- 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

Difficulties

- Not too many features
- Randomness in daily basis

Method

- Linear Regression

Data

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

Variables

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

Input file

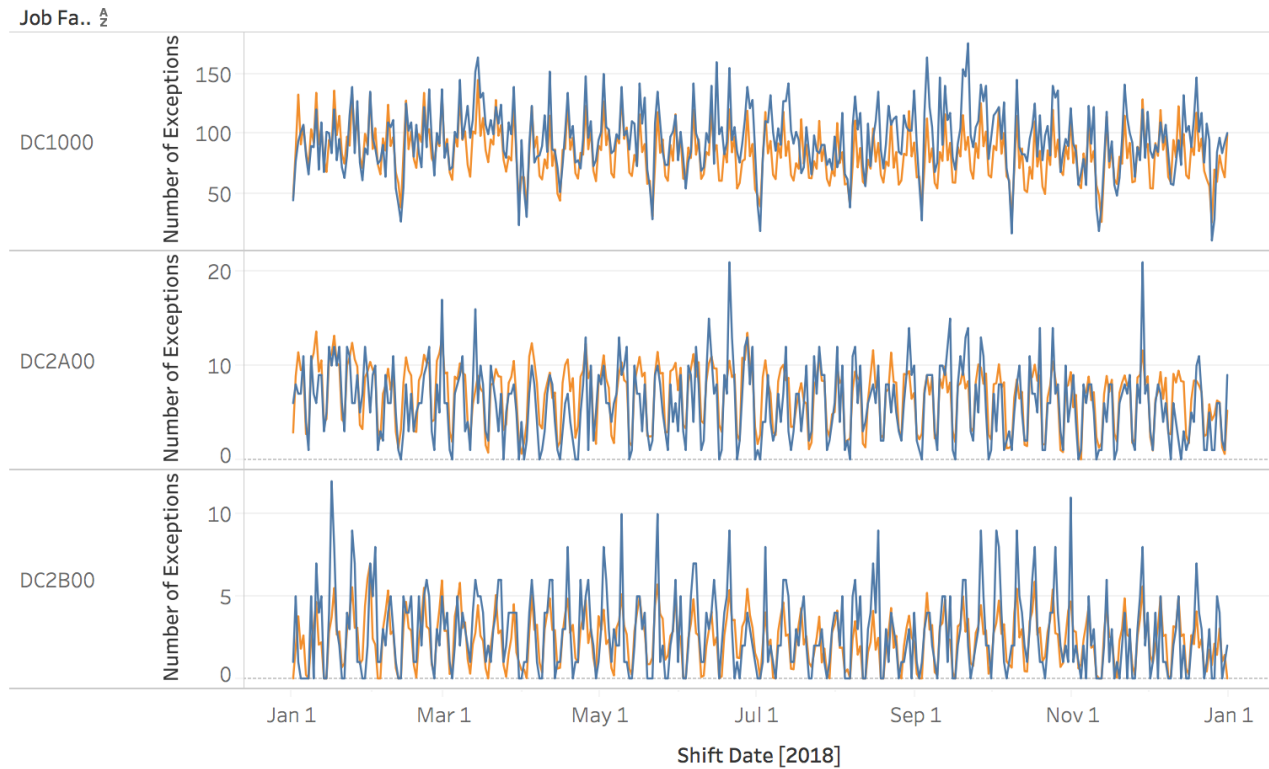
- Exception Hours for past years
- Productive Hours for past years
- Productive Hours for the period you want to predict (estimation)

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	
Overall	0.841	0.794	0.800
Straight Time	0.936	0.823	0.830
Overtime & Beyond	0.638	0.735	0.756
Relief Not Needed	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

Shift Date: 2018-05-23 to 2018-09-05

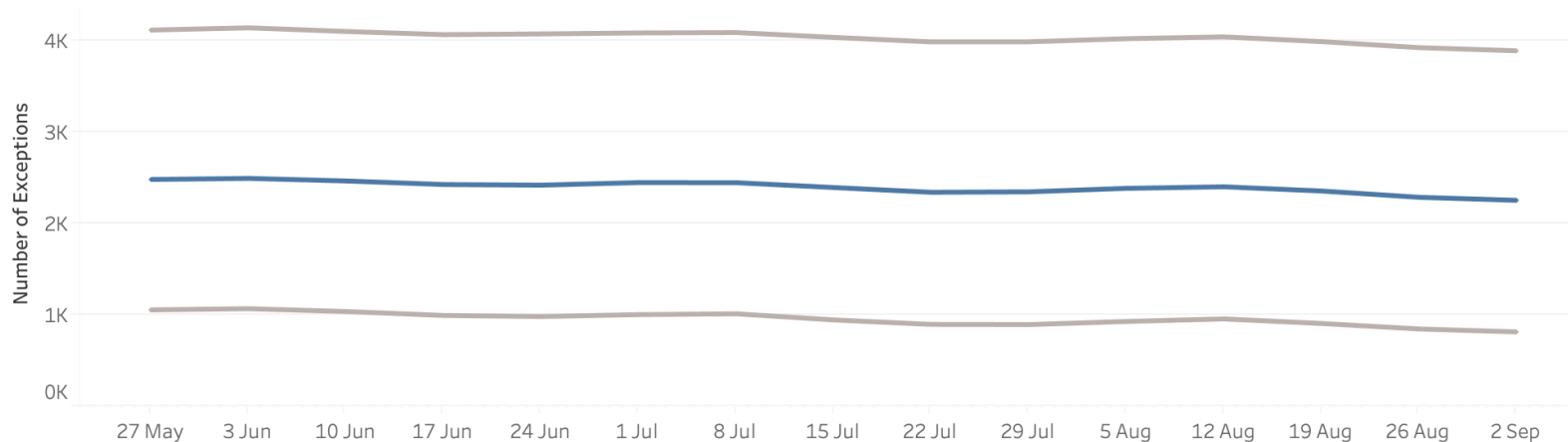
Site: St Paul's Hospital

Sub Program: (All)

Job Family: (Multiple values)

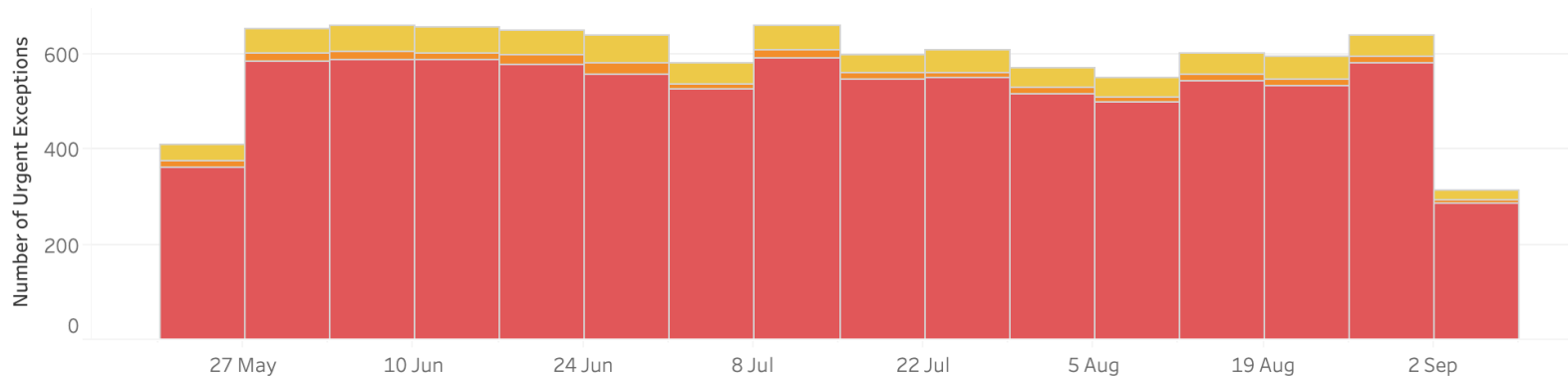
Legend: Exceptions Predicted (Blue), 95% CI - Lower Limit (Light Brown), 95% CI - Upper Limit (Dark Brown), DC2A00 (Yellow), DC2B00 (Orange), DC1000 (Red)

Predicted Number of Exceptions
(St Paul's Hospital, All, DC1000 & DC2A00)



Predicted Number of Urgent Exceptions*
(All PHC Facilities)

*Considering as Overtime and Relief Not Found



Exceptions Classification

Exceptions Classification				
Month of Shift Date	Site	Overtime and Beyond	Relief Not Needed	Straight Time
July	Brock Fahrni	21		71
	Holy Family	34		133
	Mt St Joseph	320	41	642
	St Paul's Hospital	1,242	312	4,065
	SVH Langara	45	3	173
	Youville Residence	30	9	63
August	Brock Fahrni	31		62
	Holy Family	38	1	148
	Mt St Joseph	234	52	699
	St Paul's Hospital	1,597	390	4,465
	SVH Langara	21		188
	Youville Residence	13	1	87

Shift Date

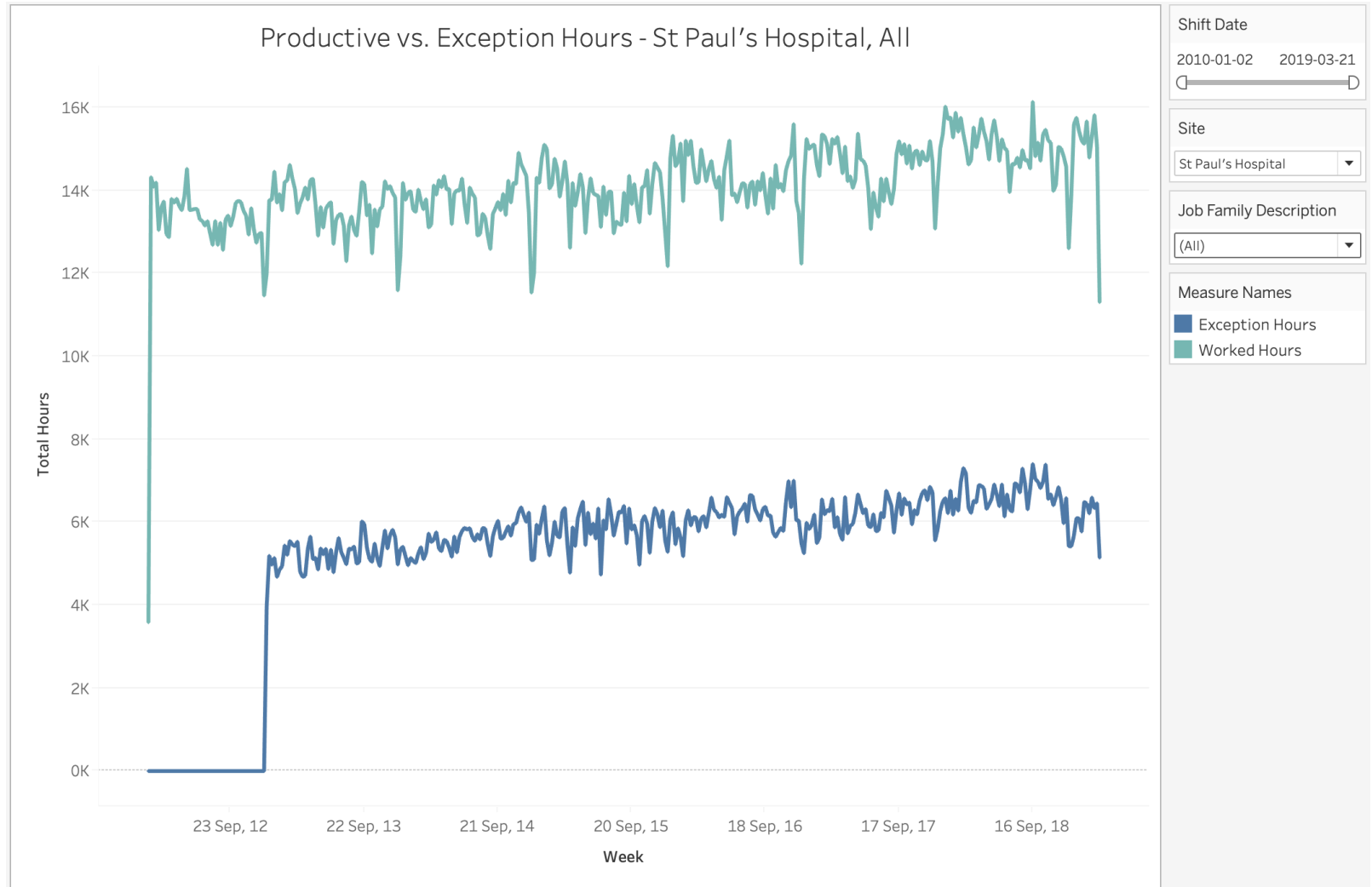
2018-07-02

2018-08-31

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!