MIE 1623 – Project 2: Forecasting

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1.0 INTRODUCTION

This assignment's objective is to forecast whether St. Julius Hospital should build a fourth OR to fulfill their C-section demand to 98% fulfilled planned surgeries. Historical data was provided for the last 52 weeks of OR surgeries, including Planned and performed as scheduled surgeries, Planned and performed not on scheduled, and Unplanned surgeries. The team forecasted using a variety of methods on both number of surgeries and OR time required for demand.

2.0 DATA EXPLORATION AND APPROACH

Some initial assumptions about the data were made as follows:

1. Hospital scheduling procedures will not change from current methods.
2. Only Unplanned surgeries will displace Planned "as sched" surgeries into Planned "not as sched" (and not overscheduling Planned surgeries etc.)

The following Figure 1 and Table 1 show initial breakdown of the data.

Sum of Filled Times			TYPE			
YEAR	Month	WEEK	PLANNED - NOT SCHED	PLANNED - SCHED	UNPLANNED	Grand Total
2013			17,517	64,683	71,977	154,177
	Apr		817	6,809	6,337	13,962
	May		2,175	7,377	8,267	17,819
	Jun		2,567	7,249	8,513	18,329
	Jul		1,570	7,883	7,265	16,718
	Aug		2,514	7,779	9,442	19,735
	Sep		2,009	7,612	7,876	17,497
	Oct		1,935	6,480	8,652	17,067
	Nov		1,844	6,785	7,385	16,015
	Dec		2,087	6,709	8,238	17,034
2014			4,292	21,435	24,243	49,970
	Jan		1,424	8,234	7,245	16,903
	Feb		1,366	6,201	8,248	15,814
	Mar		1,502	7,000	8,750	17,253
Grand Total			21,809	86,118	96,219	204,147

Figure 1: Pivot OR Time Data

Currently, the hospital is operating at 80% planned as scheduled rate.

$$\frac{86{,}118}{21{,}809 + 86{,}118} = 0.8$$

Table 1: Breakdown of the data given

CS Type			Number of CS
NULL			52
Planned	Planned as scheduled:	897	1,110
	Planned not as schedule	213	
Unplanned	Unplanned -	2	1,088
	Unplanned-crash	74	
	Unplanned –Urgent	972	
		Total	2,210

Figure 2 and Figure 3 shows the graphed week to week counts and OR Time of planned (sched and unsched) and unplanned surgeries occurring over the 52 weeks respectively. Unplanned has the most degree of variability and unpredictability and is assumed to be the driver of the conversion from planned as sched to planned not as sched.

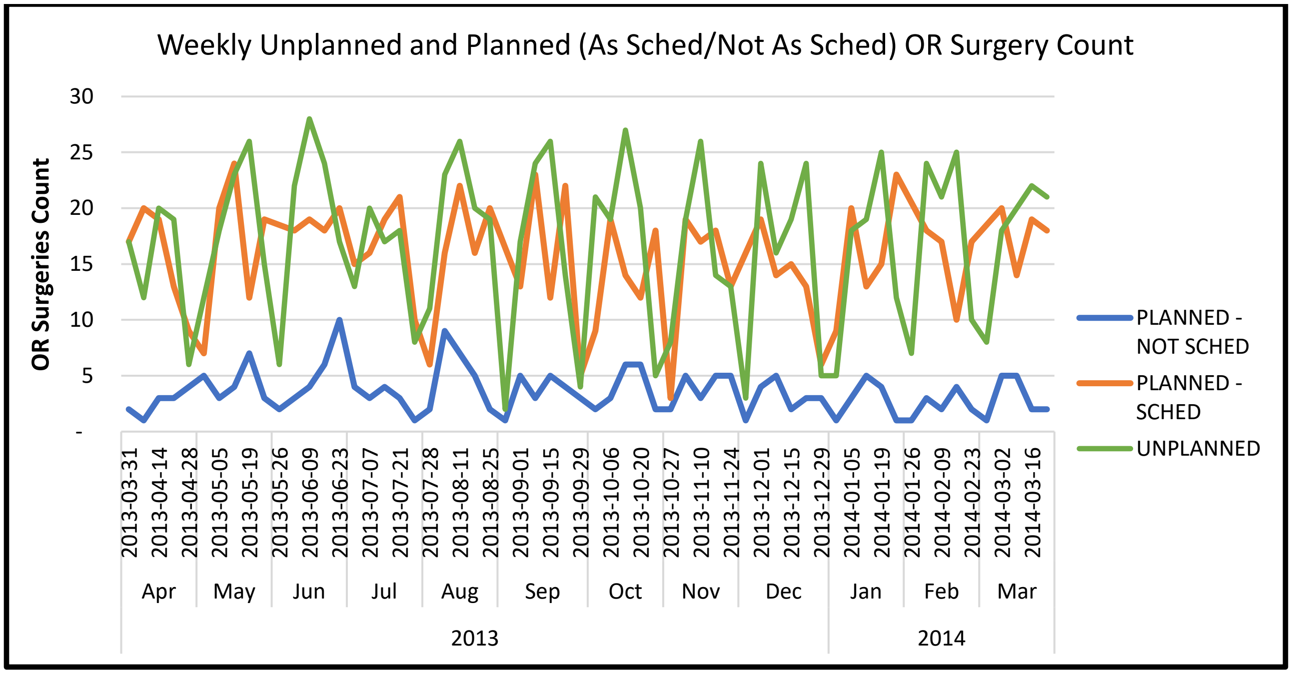

Figure 2: Graphed surgery counts of Planned (as sched and not as sched) and Unplanned

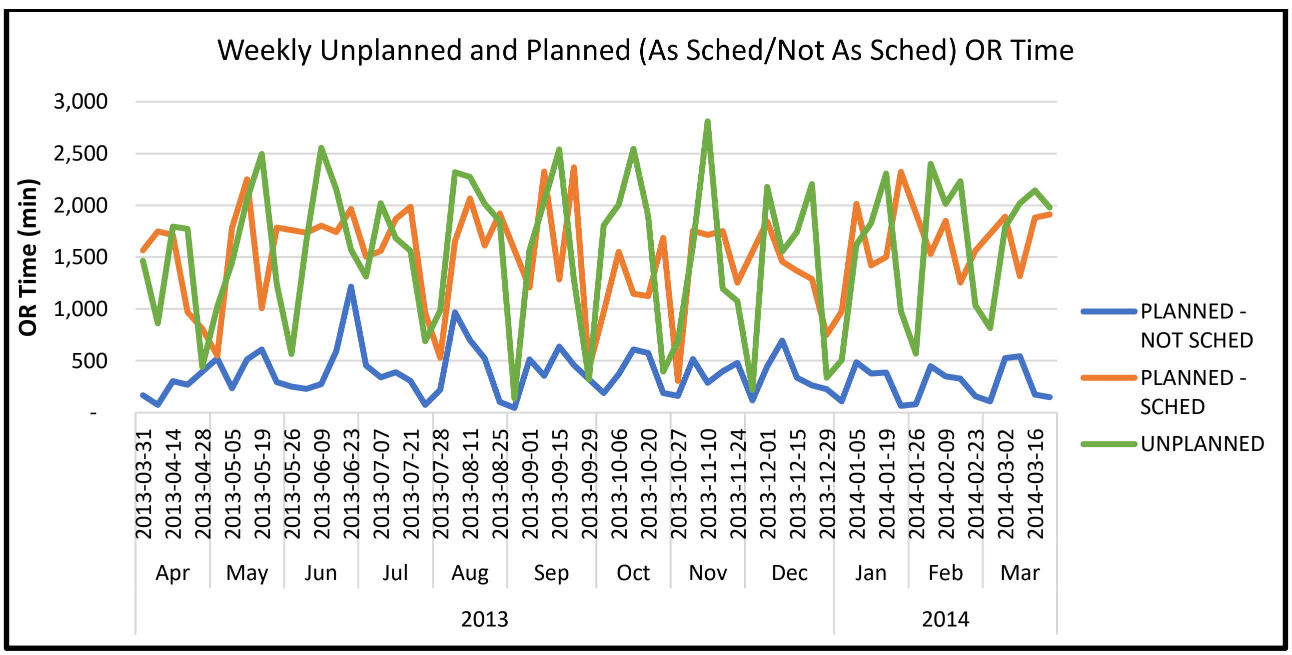

Figure 3: Graphed OR time of Planned (as sched and not as sched) and Unplanned

3.0 QUESTIONS

3.1 What data cleaning did you do?

The following cleaning of the data was done as shown in Table 2.

Table 2: Data Cleaning Steps

Data Row/Column	Description	Data Cleaning/Assumptions
Total Patient OR Time	#VALUE - inputs where either OR Arrival Time or Departure time was not logged	Daily average is assumed to be representative of the missing data
Total Patient OR Time	#NUM – Incorrect times were logged/switched (only 3 cases)	Removed from analysis
CS Type	NULL	Weekends are unplanned – but in order to not skew the data, assume remove from analysis
CS Type	Unplanned-urgent Unplanned-crash Unplanned-	Aggregate into "UNPLANNED" bucket
Week of 2014-03-30	Only three entries (Mondays) were inputted	Removed from analysis

Data Aggregation:

The data was grouped into weekly buckets, for a total of 52 weeks (1 year) for analysis.

As the total planned surgeries is the amount the hospital must fulfill without any unplanned surgeries, an extra column was also made to aggregate planned data (as sched and not as sched) to evaluate overall demand of all planned surgeries in the future.

Groupings per month and year were also made to facilitate graphing of the 52 week period.

3.2 Does the cleaned data display seasonality or trends?

Figure 4 shows the slight downward trend, in the linear estimation of the data. However, it is very minimal and could be considered negligible. Figure 5 shows semblance of seasonality in monthly periods, where the first and last seem to have low hours, and the middle of the month has peak house. However, given only 12 months, this seasonality may not be entirely consistent in frequency, and may simply be a temporary cycle or pattern driven by other factors.

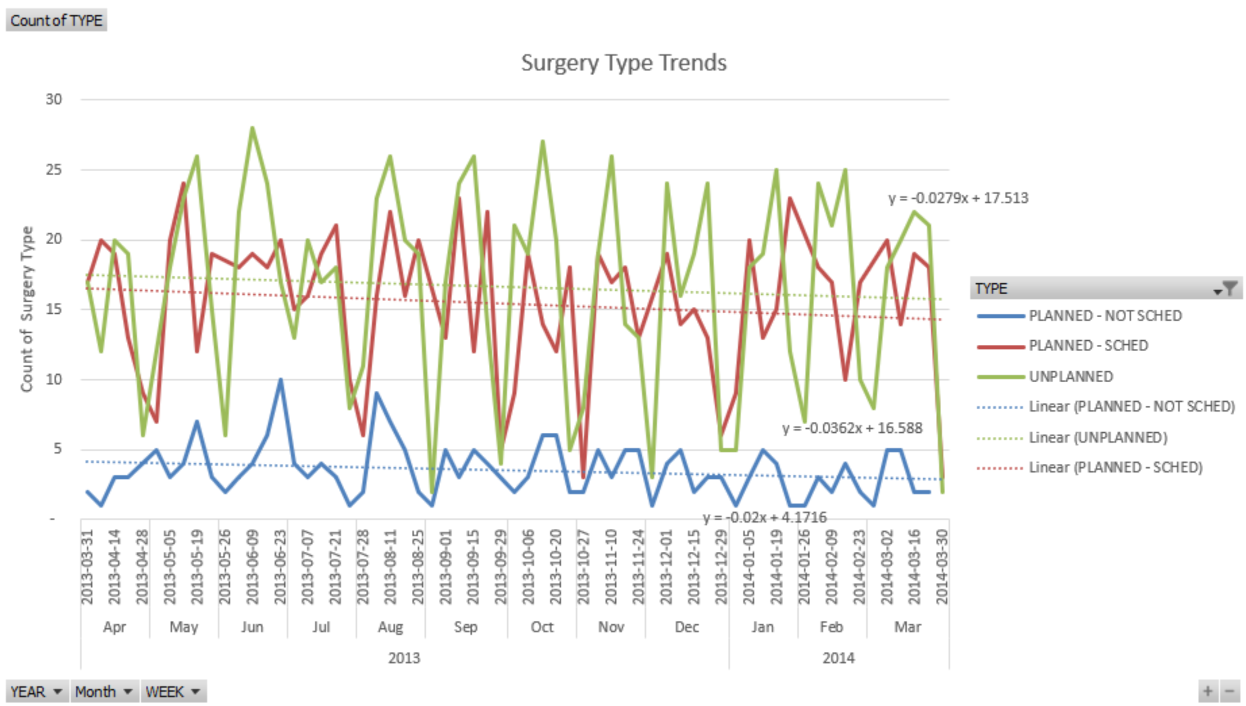

Figure 4: Surgery Type Trend

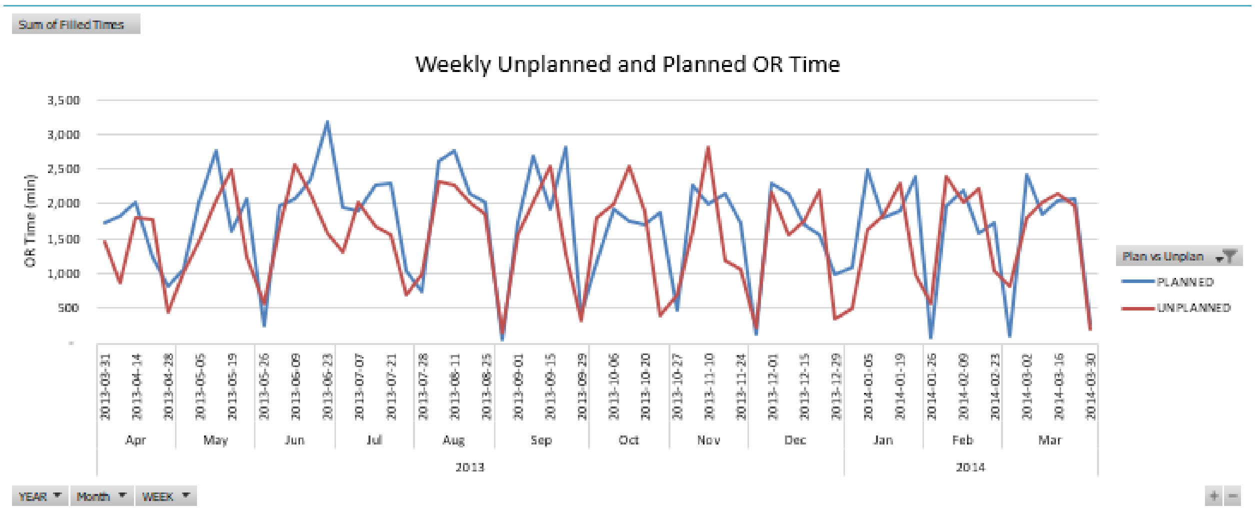

Figure 5: Surgery Type Seasonality

3.3 What forecasting methods are appropriate for this type of data?

Linear regression was eliminated as it was deemed too simplistic for the possible seasonality and variations seen in the data. For moving average, weighted moving average and exponential smoothing, the data was taken as stationary, and the minor trend was seen as negligible. Lastly, Holt's double and triple methods were used assuming seasonality and trend in data are consistent year over year. The summary of the forecasting techniques is shown in Table 3.

Table 3: Forecasts done on data.

Graph	Appendix Reference
OR Time Planned	Appendix A
OR Time Unplanned	Appendix A
OR Surgery Number Count – Moving Average	Appendix B
OR Surgery Number Count – Double Exponential	Appendix B
OR Surgery Number Count – Holt-Winters	Appendix C
OR Number Total	Appendix D

The team chose to forecast OR Time for Planned and Unplanned to see if hours would increase and exceed capacity of the OR rooms in the future. Similarly, forecast was done for the total number of surgeries for each type to see if any emerging increasing patterns for unplanned would shift more planned as sched to planned not as sched in the future. Lastly, the total number of surgeries was forecasted to get an idea of the overall general trend of all possible surgeries in the future. A sample forecast is shown in Figure 6.

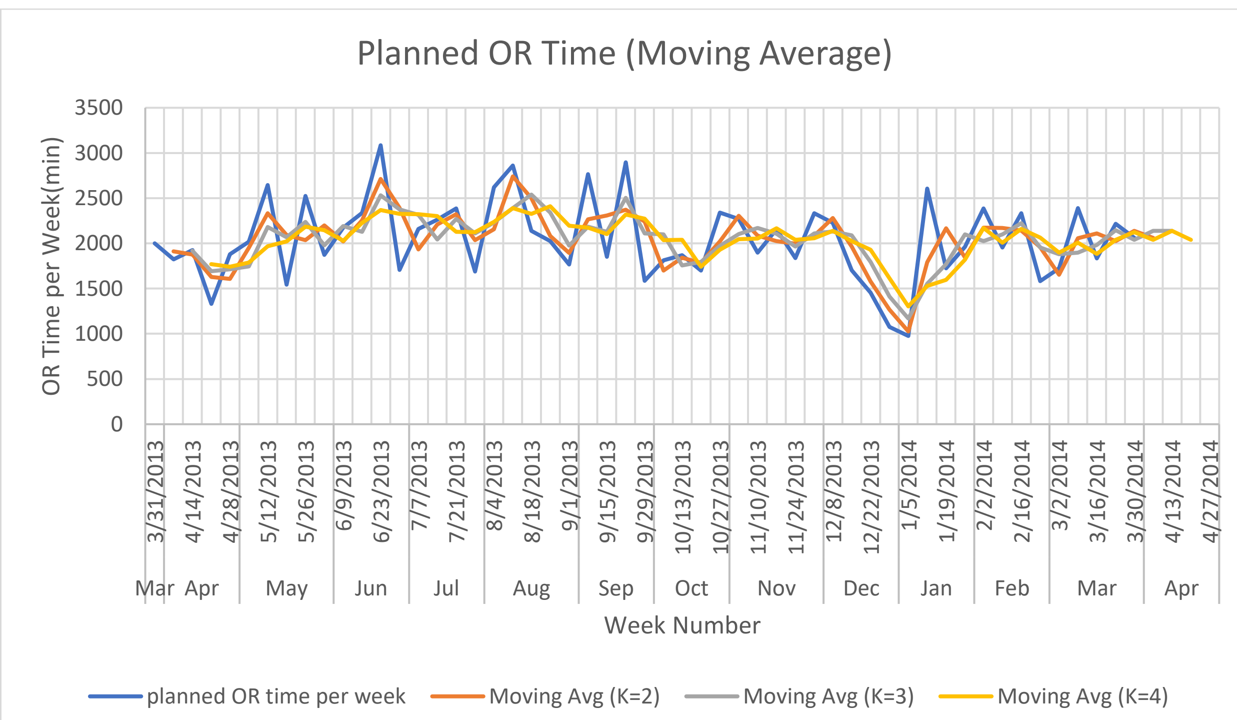

Figure 6: Moving Average Forecast on Planned OR Time

3. **What is the MAD and MSE of each of your forecasting methods?**

Table 4 summarizes the MAD and MSEs of the forecasts. Alpha, Beta, Gamma values were optimized using Excel solver.

Table 4: MAD and MSE of forecasts

	Moving Average	Weighted MA	Exponential Smoothing	Seasonal Exponential	Holt- Winters
OR Time Planned	2-weeks MAD: 250.4 MSE: 97341.05	4-weeks MAD: 409.3 MSE:232387.56	MAD:342.2 MSE:188038.05 Alpha:0	N/A	MAD:403.6 MSE:253539.1 Alpha: 0.18 Beta: 0 Gamma: 0.19
OR Time Unplanned	2-weeks MAD:233.6 MSE:86396.4	4-weeks MAD:336.2 MSE:206577.9	MAD:338.6 MSE:214322.5 Alpha:0.0096	N/A	MAD:438.8 MSE:306357.9 Alpha: 0 Beta: 0 Gamma: 0.23
OR Number Planned As Sched	2-weeks MAD: 2.55 MSE:13.41	N/A	N/A	MAD: 3.338 MSE: 15.84 Alpha: 0.14 Gamma: 0.07	N/A
OR Number Planned Not as Sched	2-weeks MAD: 0.89 MSE: 1.18	N/A	N/A	MAD: 1.721 MSE: 3.81 Alpha: 0.3 Gamma: 0.21	N/A
OR Number Planned Total	2 - weeks MAD: 2.52 MSE: 14.15	N/A	N/A	MAD: 3.222 MSE: 13.83 Alpha: 0.13 Gamma: 0.39	MAD: 2.66 MSE:12.43 Alpha: 0.13 Beta: 0 Gamma: 0
OR Number Unplanned Total	2 - weeks MAD: -0.32 MSE: 17.14	MAD: MSE:	MAD: MSE:	MAD: 3.961 MSE: 24.66 Alpha: 0.33 Gamma: 0.19	N/A
OR Number Total	5-weeks MAD: 4.54 MSE: 5.8 MAPE: 10.85%	5 weeks MAD:4.52 MSE:5.8 MAPE:10.82%	MAD:4.18 MSE: 5.4 MAPE: 10.01%	MAD: 5.61 MSE: 7.1 MAPE: 7.16 Alpha: 0.54 Beta: 0.23	N/A

As shown in Appendix A, both planned and unplanned OR time in relation to weeks show no obvious trend or seasonality. Therefore, we choose the moving average, weighted moving average, exponential smoothing and Holts-Winter method to forecast the OR time in the future. Moving average of two weeks (K=2) gives the best MAD and MSE value comparing to other methods for both planned and unplanned scenarios. Based on MAD and MSE, moving average is the best way to forecast future OR time.

As shown in Table 4 above, Moving Average (MA), Weighted MA (WMA), Exponential Smoothing (ES), and Double Exponential Smoothing (DES) were preformed on all the CS type patients. For both the MA and WMA a 5 week and 10 week lookahead were performed which can be found in the attached excel file. Using the 5 week lookahead yielded a lower MAD, MSE, and in turn a lower MAPE value. Overall, out of the 4 forecasting methods used, exponential smoothing yielded the lowest MAD and MSE values.

Similarly, MA, Seasonal exponential and Holt-Winters techniques were used to forecast the OR surgery count for the various CS buckets individually. These forecasts served to help predict the demand of specific CS types, notably unplanned and planned aggregated data. The lowest error observed for Planned total was the Holt-Winters, when assuming both trend and seasonality in the data are valid. If the assumption for trend and seasonality is not valid, then the moving average would be the best forecasting method with the lowest error.

Using these forecasts and the OR capacity, the question to investigate becomes whether the unplanned demand will exceed the capacity of all planned surgeries. Assuming the demand is all of the combined time, the capacity will help determine at which point the unplanned surgeries start pushing out more and more planned surgeries.

5. Do you trust your forecasts? Why or why not?

We would not trust the forecasts results. The main reason is due to the lack of data available. Some of the forecasting methods are based on trend and seasonality, but with only a year worth of data, especially grouped into weeks, the data may not reflect these patterns completely. Additionally, errors were still quite high comparatively, as the techniques are based off assumed trend and seasonality data that the data doesn’t not completely reflect. It is difficult to tell if seasonality (such as the differences between summer and winter months) exists consistently with only one year of data. With limited amounts of data (only 1 year), it is difficult to measure the accuracy of the forecast. Without knowing whether the cyclical trends observed per week by month are consistent, the forecast should not be used to accurately predict demand. To get a better forecast, more data is needed.

6. When do you recommend that SJH build a fourth OR, if at all?

It is difficult to recommend if SJH should build a fourth OR or if the three ORs they have currently is adequate. More data is required such as the capacity of the three ORs. Additionally, a correlation between the number of planned surgeries that are pushed out due to urgent surgeries and not due to other factors such as staff shortage on specific days or planned as schedule surgeries taking longer than expected, and between unplanned surgery is needed.

However, utilizing the double exponential smoothing forecasting method, the total CS Type was graphed and forecasted a month ahead as shown in Appendix D. The forecast displayed that the total amount of CS will increase, however it is not clear which CS type will increase therefore the data was broken up into planned as scheduled, planned not as scheduled, and urgent CS then forecasted a month ahead. As shown in Appendix D, the planned as scheduled is forecasted to increase, the planned not as scheduled is forecasted to decrease and urgent CS is forecasted to stay the same with a slight increase. With the planned as scheduled surgeries forecasted to increase, planned not as scheduled forecasted to decrease, and urgent CS forecasted to stay the same, the SJH will eventually hit the 98% planned as scheduled surgeries however, without knowing the capacity of the ORs a definite answer cannot be provided.

Further factors that can affect the need for a fourth OR include scheduling efficiency. As seen in Figure 7, There is a lower number of planned surgeries on Thursday. It is unclear whether this is below the capacity of the OR, but the hospital can potentially look into changing their scheduling patterns to allocate more planned surgeries for Thursdays. This could reduce the need for a 4th OR to a later time and could help reach the 98% goal.

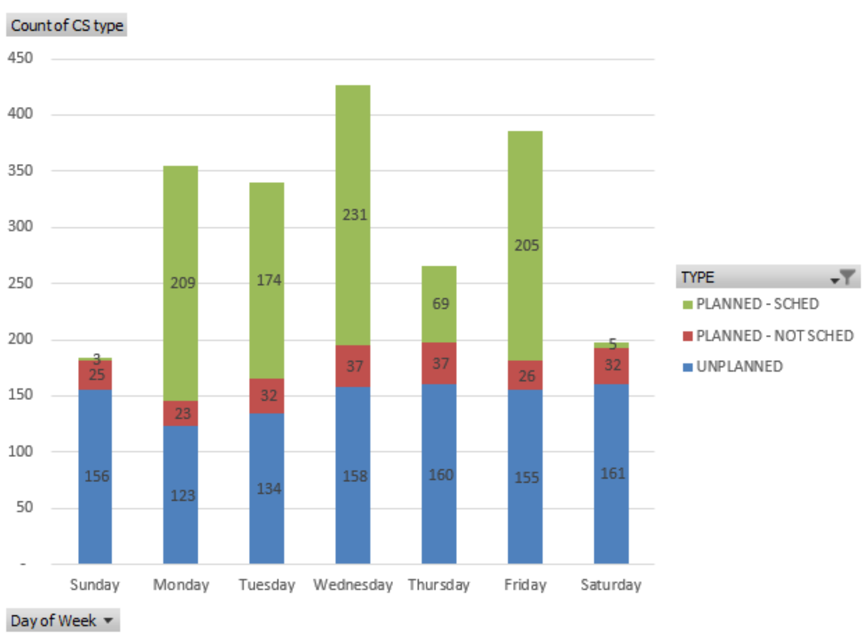

Figure 7: Count of CS Type per Day of Week

Appendix A

A.1 Planned OR Time Forecast

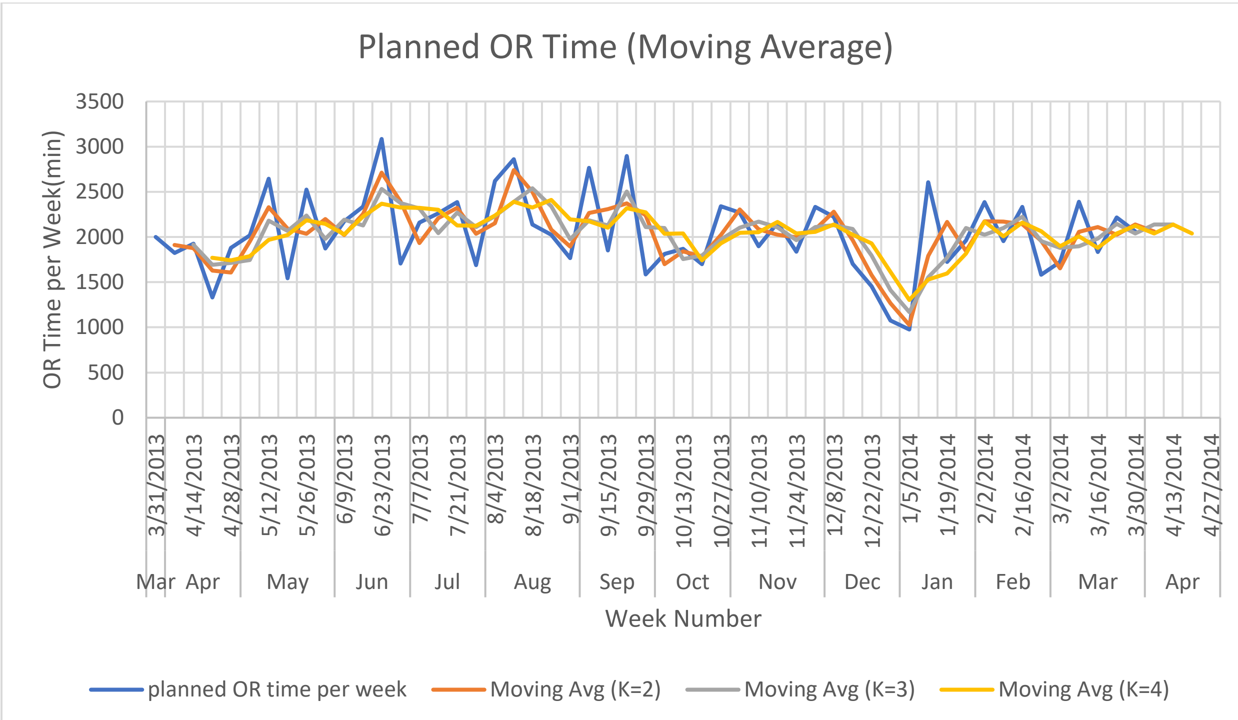

Figure A.1.1: Planned OR time forecasted with moving average method

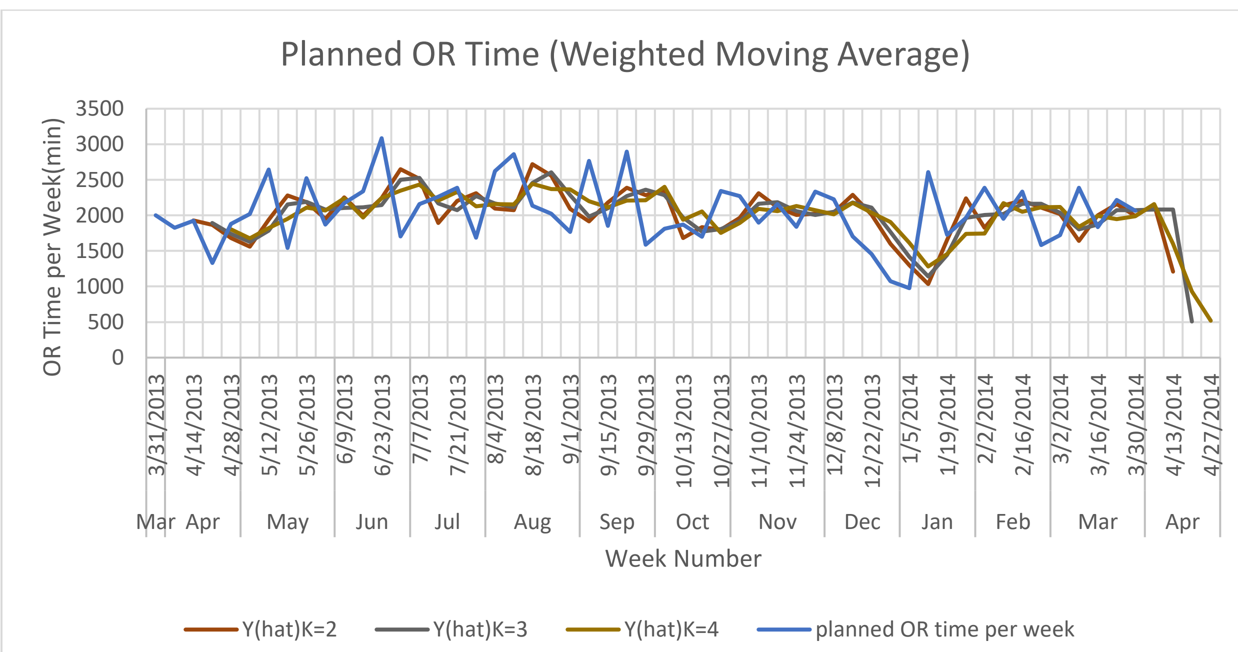

Figure A.1.2: Planned OR time forecasted with weighted moving average method

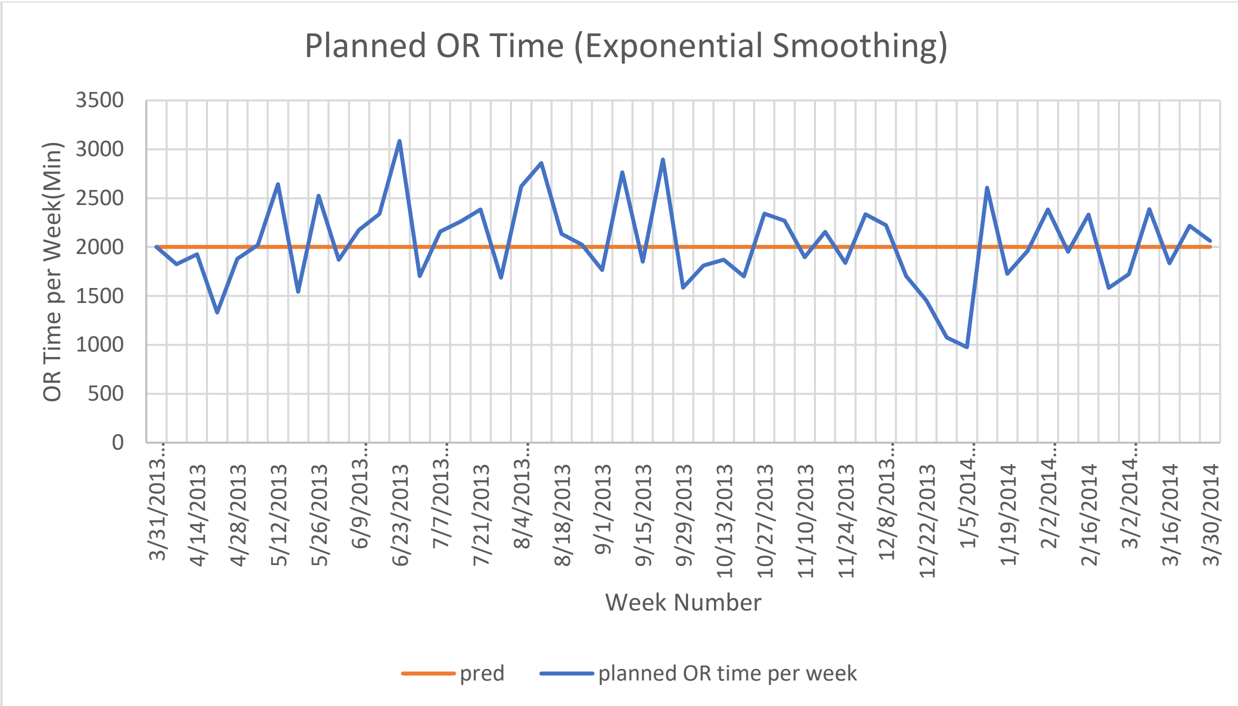

Figure A.1.3: Planned OR time forecasted with exponential smoothing method

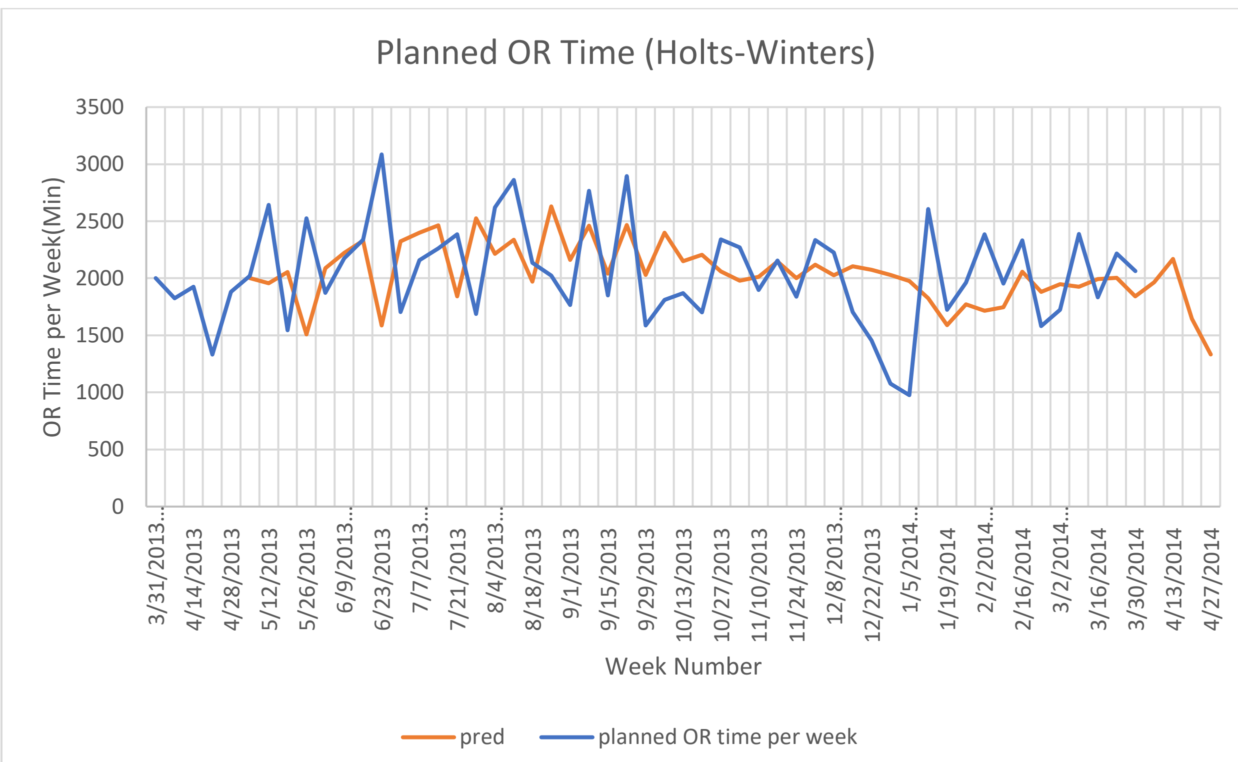

Figure A.1.4: Planned OR time forecasted with Holts-Winter method

A.2 Unplanned OR Time Forecast

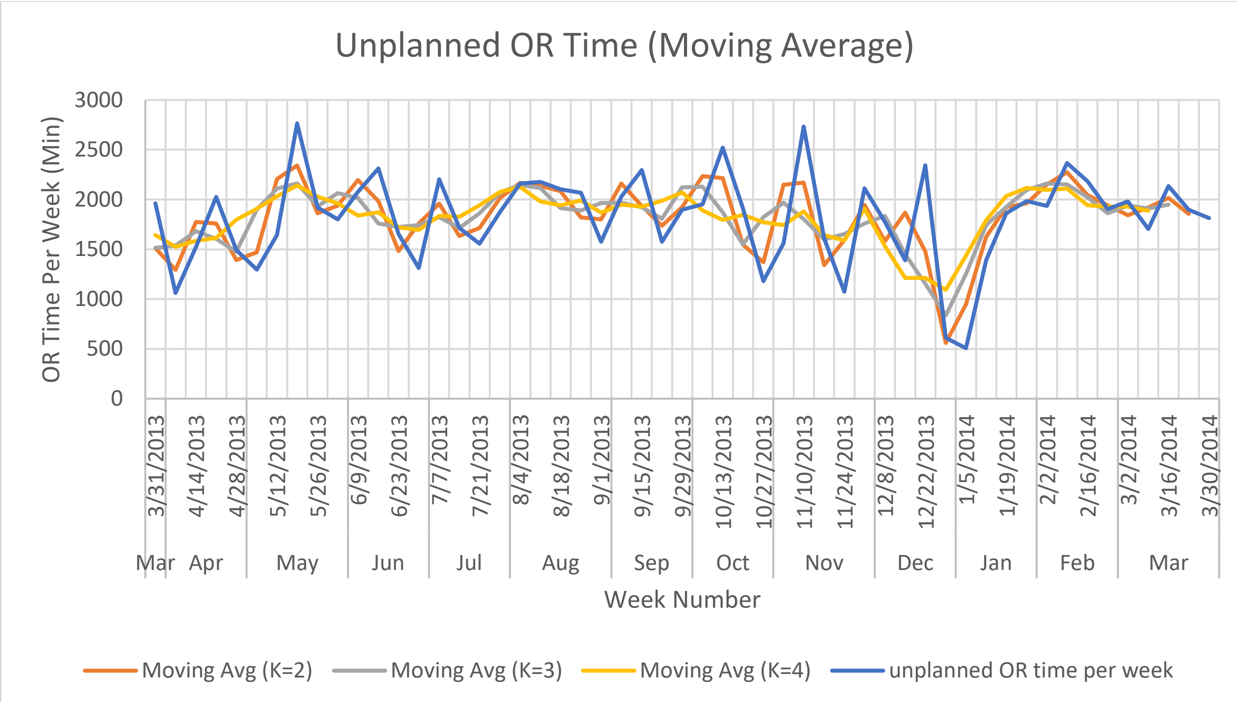

Figure A.2.1: Unplanned OR time forecasted with moving average method

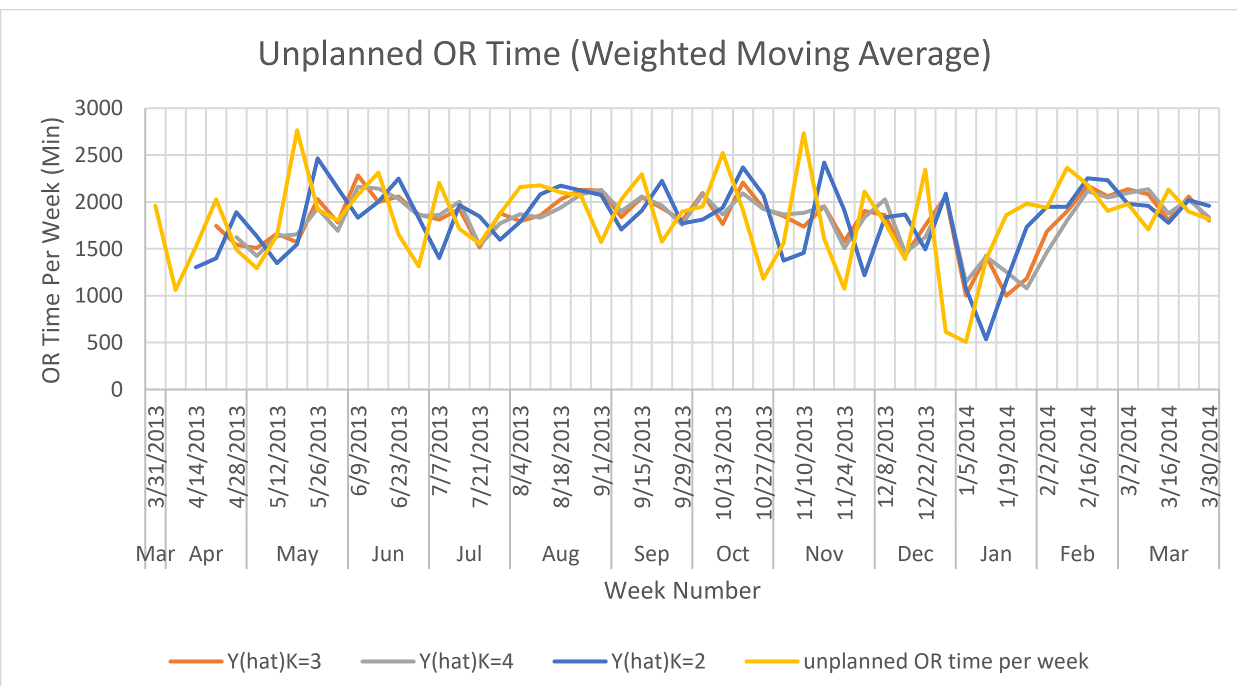

Figure A.2.2: Unplanned OR time forecasted with weighted moving average method

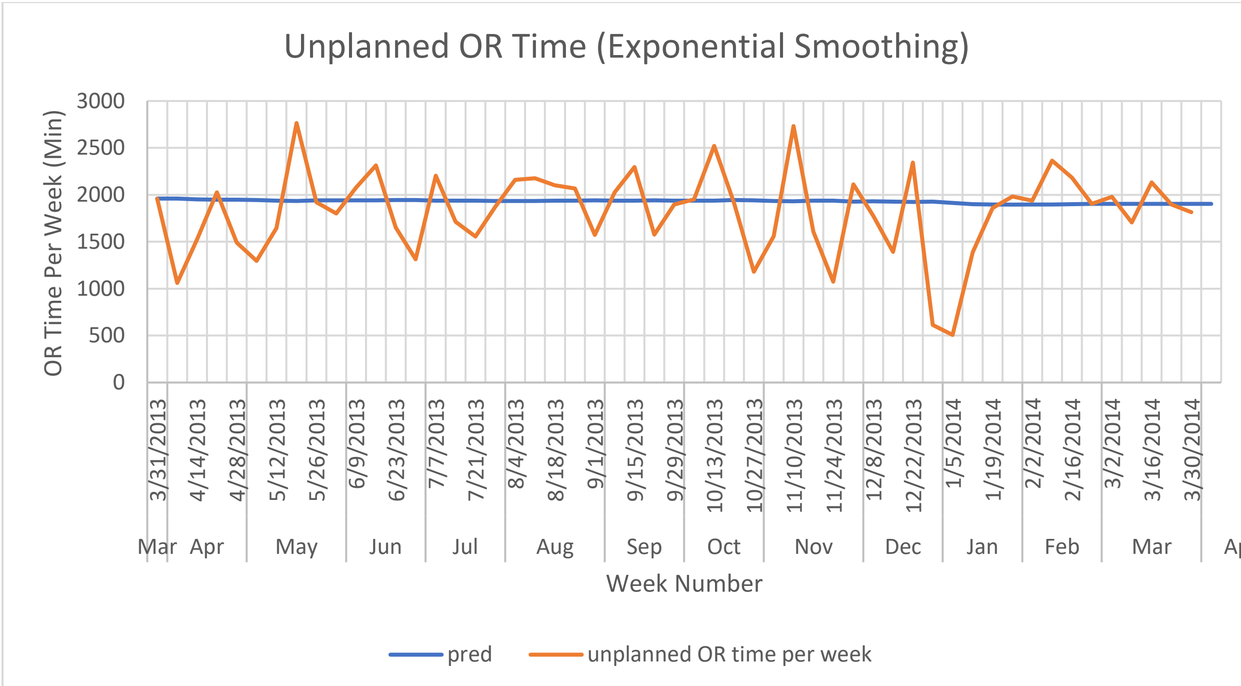

Figure A.2.3: Unplanned OR time forecasted with exponential smoothing method

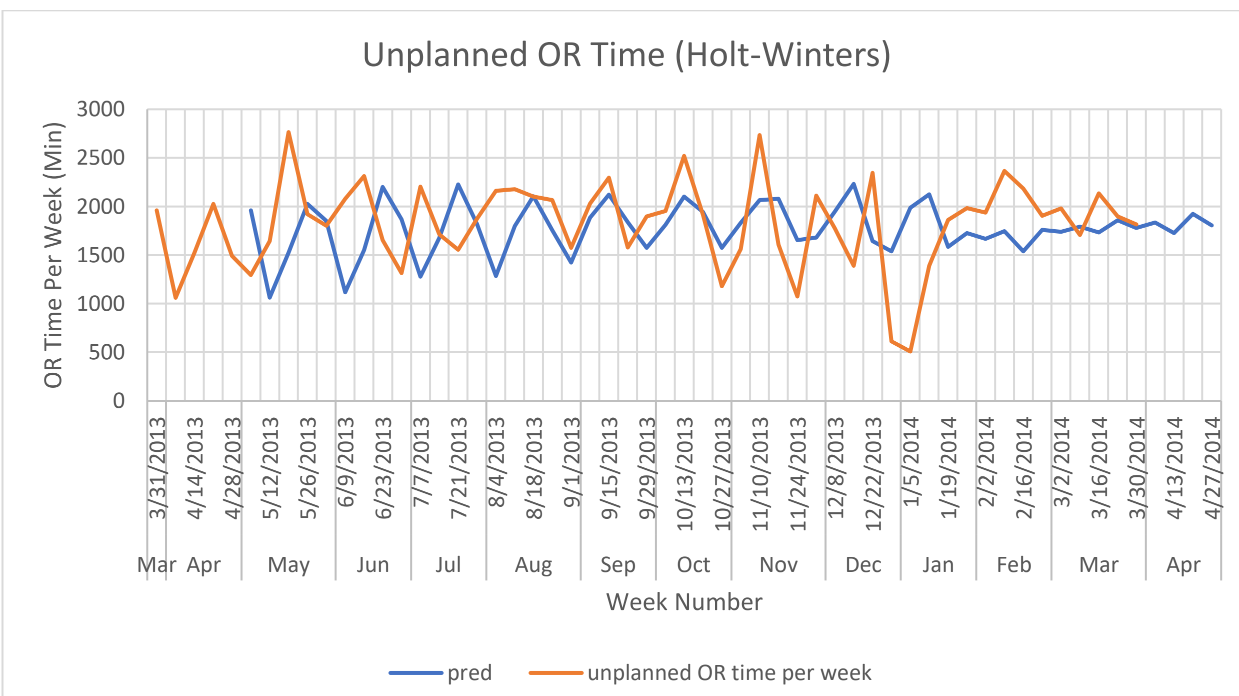

Figure A.2.4: Unplanned OR time forecasted with Holts-Winter method

Appendix B

Figure B.1- 2 week moving average for Planned and Unplanned Surgery Counts

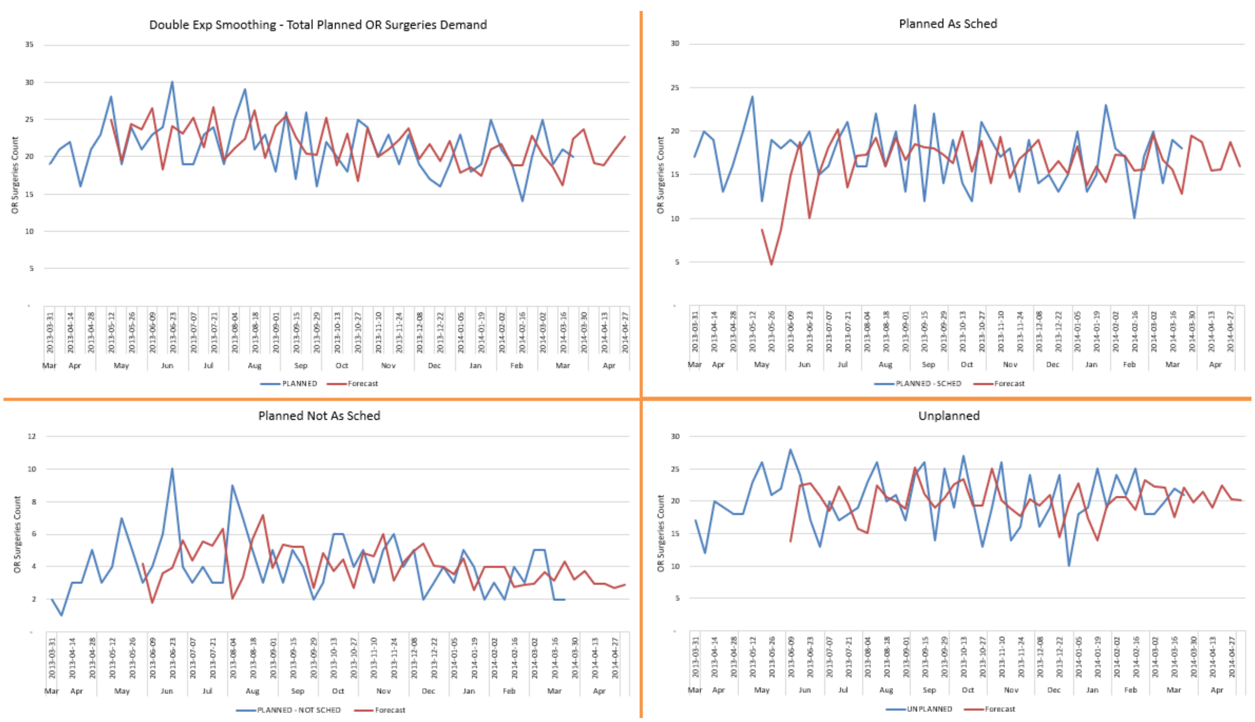

Figure B.2 - Double Exponential - Seasonality for Planned and Unplanned Surgery Counts

Appendix C

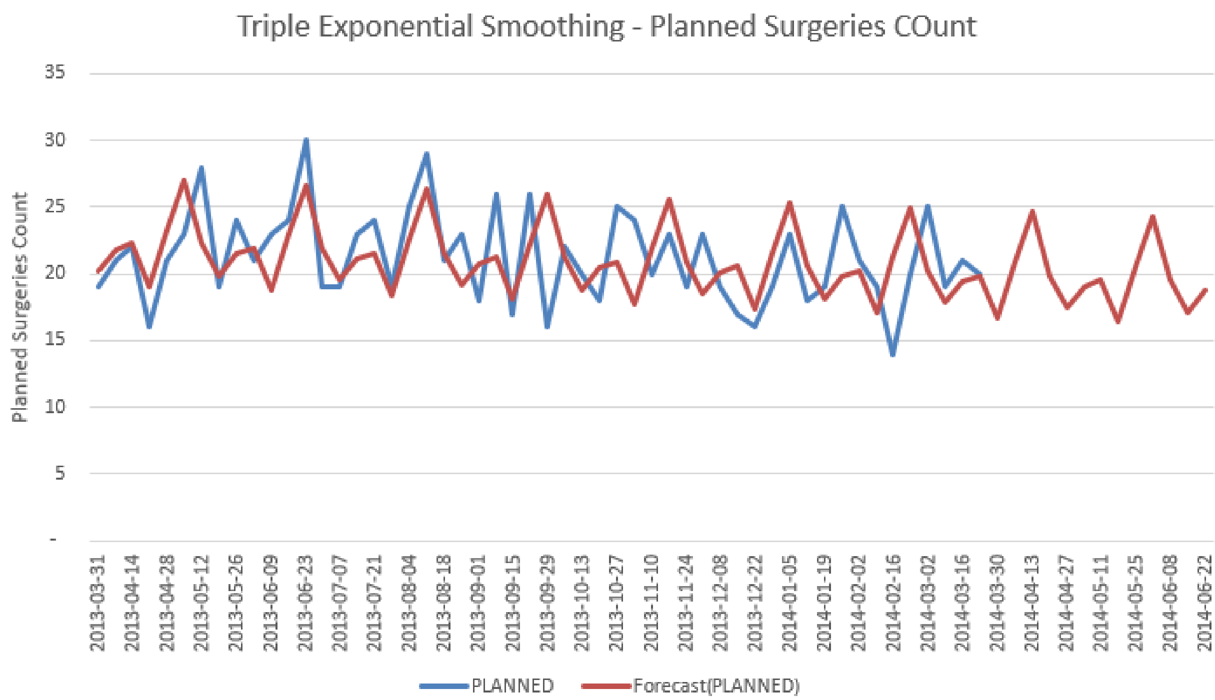

Figure C.1: Holt-Winters Forecasting on Total Planned Surgery Count

Appendix D

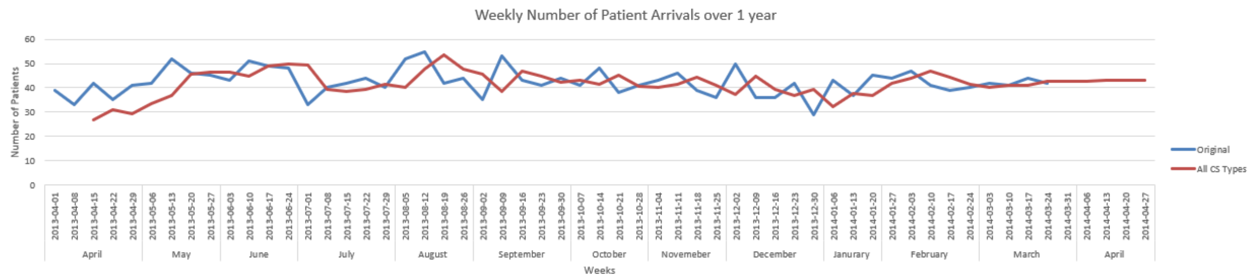

Figure D.1: Weekly number of all CS type patient’s arrival over 1 year forecasted using double exponential smoothing.

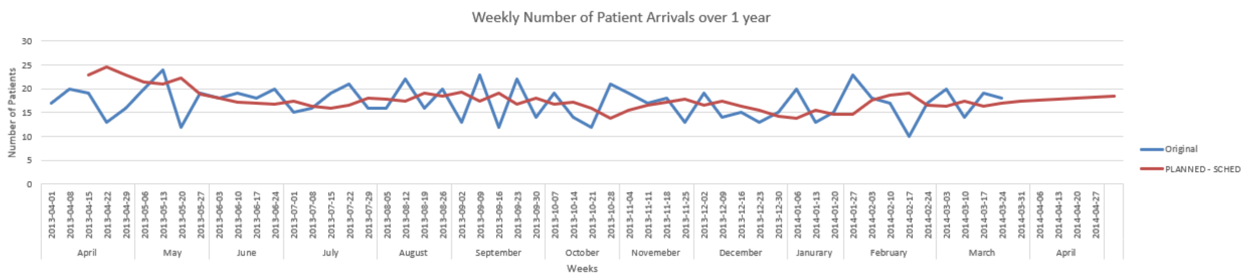

Figure D.2: Weekly number of all planned as scheduled patients arrival over 1 year forecasted using double exponential smoothing.

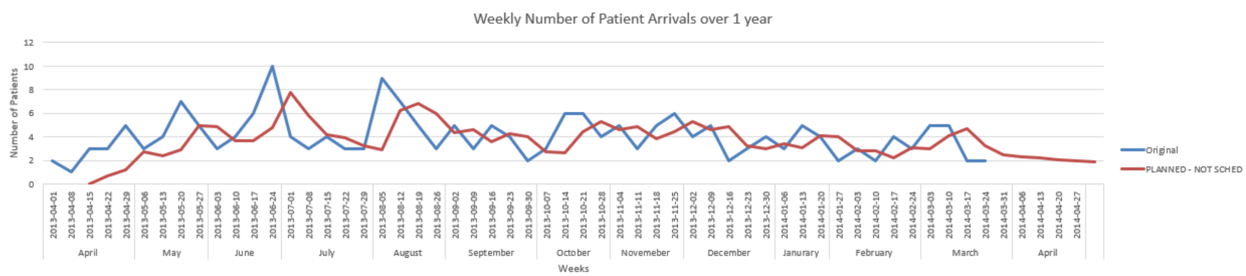

Figure D.3: Weekly number of all planned not as scheduled patients arrival over 1 year forecasted using double exponential smoothing.

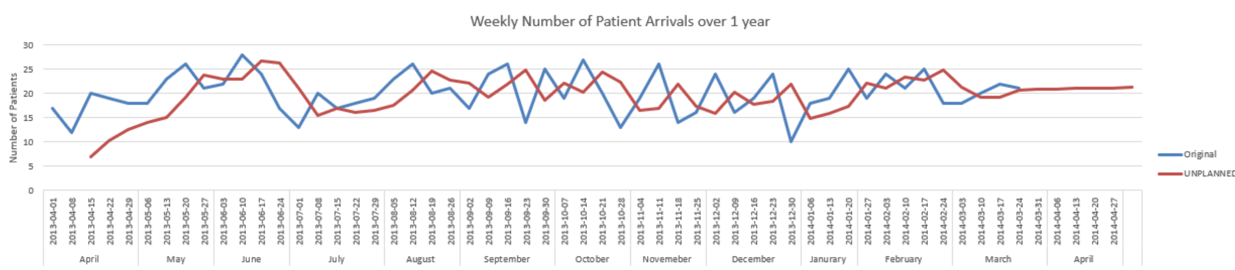

Figure D.4: Weekly number of all unplanned scheduled patient's arrival over 1 year forecasted using double exponential smoothing.