Forecasting with seasonal trends at BLAYK restaurant

Fortune Walla

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Objective

Introduction

You are the lead demand planner for Beers Looking At You, Kid (or BLAYK) a restaurant that features sandwiches, appetizers, and, of course, beer. The restaurant is known for its very fresh beer so the management tries to monitor beer consumption by each shift. You have been tasked to look at how the beer consumption is being forecasted in order to improve the quality and lower the costs of having fresh beer.

There are four shifts in each day the restaurant is open:

Shift 1from 11 AM to 2 PM

Shift 2from 2 PM to 5 PM

Shift 3from 5 PM to 8 PM

Shift 4from 8 PM to 11 PM

The fields in the spreadsheet are:

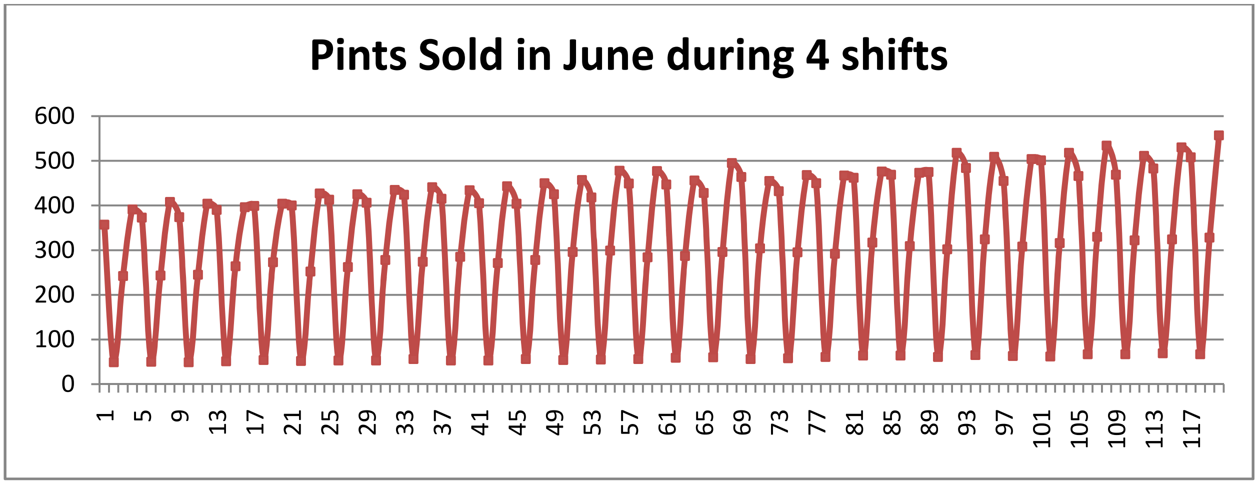
Time Period (t) – a sequential numbering of each shift in your data from 1 to 120

Date – the date of the record

Shift Number – the shift number for that record (1, 2, 3, or 4), and

Pints Sold – the number of pints of beer sold on that day during that shift.

Visualization of the raw data



Initial Seasonality Factors

The above diagram clearly points to a seasonality of the sales.

Since at this point it is not very clear as to whether there is a trend in the data or not, we find use two methods to find the seasonality factors.

Assuming no trend

With no trend the seasonality factors (SF) need not be normalized each season.

SF per period = total sales per shift / (total sales per month/no. of periods)

Also

SF per period = total sales per shift / average no. of sales per period

Mathematically we can express it as

$$F_i = \frac{\sum_{t=1}^{n} \mathrm{D_t} \; \forall \; \mathrm{t} \in \mathrm{i}}{(\sum_{t=1}^{n} \mathit{Applications\ of\ Functional\ Analysis}\mathrm{D_t})/\mathrm{P}}$$

Centered Moving Average Method (CMA)

Since each season has 4 periods, we use 4-point Centered Moving Average. Here since the season has an even number of points. We need to take the moving average of the season from both sides & then take the final average.

Below is a sample of the data used to calculate part of the Fi’s

MATop is the average of Shift 1,2,3 & 4

MABottom is the average of Shift 2,3,4 & 5

MA_Avgi is the average of MATop & MABottom.

Each Fi is the xi/MA_Avgi except the first two & last two of the time series. The first two & last two Fi are calculated by first & the last MA_Avg values respectively.

Time Period (t)	Date	Shift Number	Pints Sold, xi	MATop	MABottom	MA_Avg i	Fi
1	1-Jun	1	357				1.363897
2	1-Jun	2	49				0.187202
3	1-Jun	3	242	260	264	262	0.924546
4	1-Jun	4	391	264	264	264	1.481762
5	2-Jun	1	373	264	264	264	1.41221
6	2-Jun	2	50	264	269	266	0.187705
7	2-Jun	3	243	269	269	269	0.904607
8	2-Jun	4	408	269	269	269	1.518846

Now if the assumption is incorrect & then is a small trend, then the sum of the factors will not add up to number of periods in a season. i.e P = 4 Hence a correction is required in the form and we simply multiply each of your Seasonality Factors by

$$\frac{\mathrm{P}}{\sum_{\mathrm{i}=1}^{\mathrm{n}} F_i}$$

Once all the Fi are calculated, we average them according to Shift Number. The summary is in the table.

	Total Pints Sold	**If equal sales per shift, pints per shift sold**	**Ratio of Sales per shift compared with average**	**4-point Moving Centered Averaged Seasonality Factors**
Entire Month	37423			
Shift 1	13045	9356	1.39432969	1.402007
Shift 2	1737	9356	0.185661224	0.185922
Shift 3	8700	9356	0.929909414	0.928191
Shift 4	13941	9356	1.490099671	1.483154
			4	3.999273

Holt-Winter Model (level+seasonality+trend)

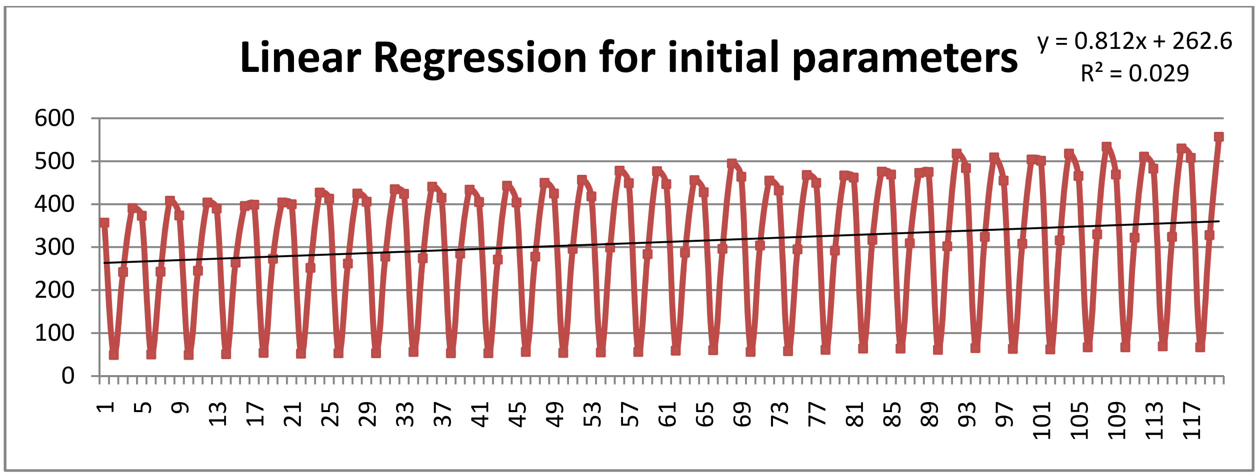
Level & Trend:

Running a linear regression we get the equation.

y = 0.812x + 262.6

From the regression equation we get a level of about 263 pints of beer per shift with an trend of 0.8 additional pints per time period. i.e.

The regression gives you an estimated level of 265 pints per each shift with a trend of 0.80 additional pints per time period. This means that the sales of beer is increasing about 3.2 pints per day. Hence there is a positive trend trend.



Seasonality

This involves estimating the initial values of the level and trend "de-seasoning" the actual demand by the Seasonality Factors we just found. Part of the data used to calculate the normalized seasonality factors.

Time Period (t)	Date	Shift Number	Pints Sold	MATop	MABottom	MA_Avg	Fi	SUM of each season	Fi Normalized	Normalized Sum
1	1-Jun	1	357				1.363897	3.957406897	1.378576309	4
2	1-Jun	2	49				0.187202	3.957406897	0.189216356	
3	1-Jun	3	242	260	264	262	0.924546	3.957406897	0.934497106	
4	1-Jun	4	391	264	264	264	1.481762	3.957406897	1.497710229	
5	2-Jun	1	373	264	264	264	1.41221	4.023368199	1.404007844	4
6	2-Jun	2	50	264	269	266	0.187705	4.023368199	0.186615088	
7	2-Jun	3	243	269	269	269	0.904607	4.023368199	0.89935273	
8	2-Jun	4	408	269	269	269	1.518846	4.023368199	1.510024337	

So taking the average of the all the normalized factors we get,

	Before Normalized	After Normalized		
Fs1	1.402007	1.402205906		
Fs2	0.185922	0.185977102		
Fs3	0.928191	0.928395676		
Fs4	1.483154	1.483421316		
SUM	3.999273	4		

Initial Parameters

Assume that Alpha=0.15, Beta=0.06 & gamma = 0.05

$$\hat{x}_{t,t+\tau} = (\hat{a}_t + \tau\hat{b}_t)\hat{F}_{t+\tau-P}$$

$$\hat{a}_t = \alpha\left(\frac{x_t}{\hat{F}_{t-P}}\right) + (1-\alpha)(\hat{a}_{t-1} + \hat{b}_{t-1})$$

$$\hat{b}_t = \beta(\hat{a}_t - \hat{a}_{t-1}) + (1-\beta)\hat{b}_{t-1}$$

$$\hat{F}_t = \gamma\left(\frac{x_t}{\hat{a}_t}\right) + (1-\gamma)\hat{F}_{t-P}$$

We have for the period 120, the following initial parameters,

Fs1	1.402205906	
Fs2	0.185977102	
Fs3	0.928395676	
Fs4	1.483421316	
a^120	360.04	0.812*(120) + 262.6
b^120	0.812	
Alpha	0.15	
Beta	0.06	
Gamma	0.05	

Using above data we can start forecasting for the coming periods 122 i.e. July 2 Shift 2

	Actual x(t)	a^i	b^ i	F^i	x^(t+4)
120	557	360	0.81		
121	520	362.3151378	0.900308265	1.403856344	513.694 (for t=125)

Using just the 122 forecast, the rest of the periods i.e. 123, 124 & 125 can be calculated using

$$\hat{x}_{t,t+\tau} = (\hat{a}_t + \tau\hat{b}_t)\hat{F}_{t+\tau-P}$$

Conclusion

As observed above, the data about beer consumption follows seasonality & has a positive trend. This can be modeled using the Holt-Winter Model. Of course, error analysis must be done to tweak the model especially the seasonality factors.