How to create a seasonal trend forecast?

Prepare a forecast for next year based on given historical data

Sales 2022		
Period	Month	Actual demand
1	Jan-22	800
2	Feb-22	1500
3	Mar-22	1550
4	Apr-22	1500
5	May-22	2450
6	Jun-22	3120
7	Jul-22	2850
8	Aug-22	2600
9	Sep-22	2990
10	Oct-22	1000
11	Nov-22	850
12	Dec-22	500

Sales 2023 (untill Aug)		
Period	Month	Actual demand
13	Jan-23	980
14	Feb-23	2000
15	Mar-23	2500
16	Apr-23	1750
17	May-23	3000
18	Jun-23	3500
19	Jul-23	4000
20	Aug-23	2900

Figure 1. Forecast example (made by the author)

Following up on my previous post about forecasting, this post focuses on creating a seasonal trend forecast by using the decomposition of time series data as it indicates a non-linear trend, meaning that it can display changes that fluctuate over time. These changes can be seen as changes in demand and supply.

In general, decomposition of time series data can be done as follows:

Step 1: Find the seasonal factor

- Determine average actual demand per specific period (e.g., per month). For example, if actual demand data for Jan, Feb, and Mar 2022 are 10, 20, and 30 respectively, then the average actual demand per month is (10+20+30)/3 = 20.
- Determine average total actual demand (e.g., per year)
- Calculate seasonal factor: average actual demand/ average total actual demand. For example, actual demand in Jan 2022, and Jan 2023 are 15, and 17 respectively. Then, the average actual demand for Jan (15+17)/2 = 16. The average total actual demand from Jan 22 to Jan 23 is 100. The seasonal factor for Jan is calculated as follows: 16/100 = 0.16

Step 2: Create a simple linear regression model by de-seasonalized demand

- De-seasonalized actual demand per specific period based on the seasonal factor (this means taking the seasonal factor out of your actual demand) = actual demand/ seasonal factor
- Use linear regression (Excel) to fit trend line to de-seasonalized data

Step 3: Create a seasonal trend forecast

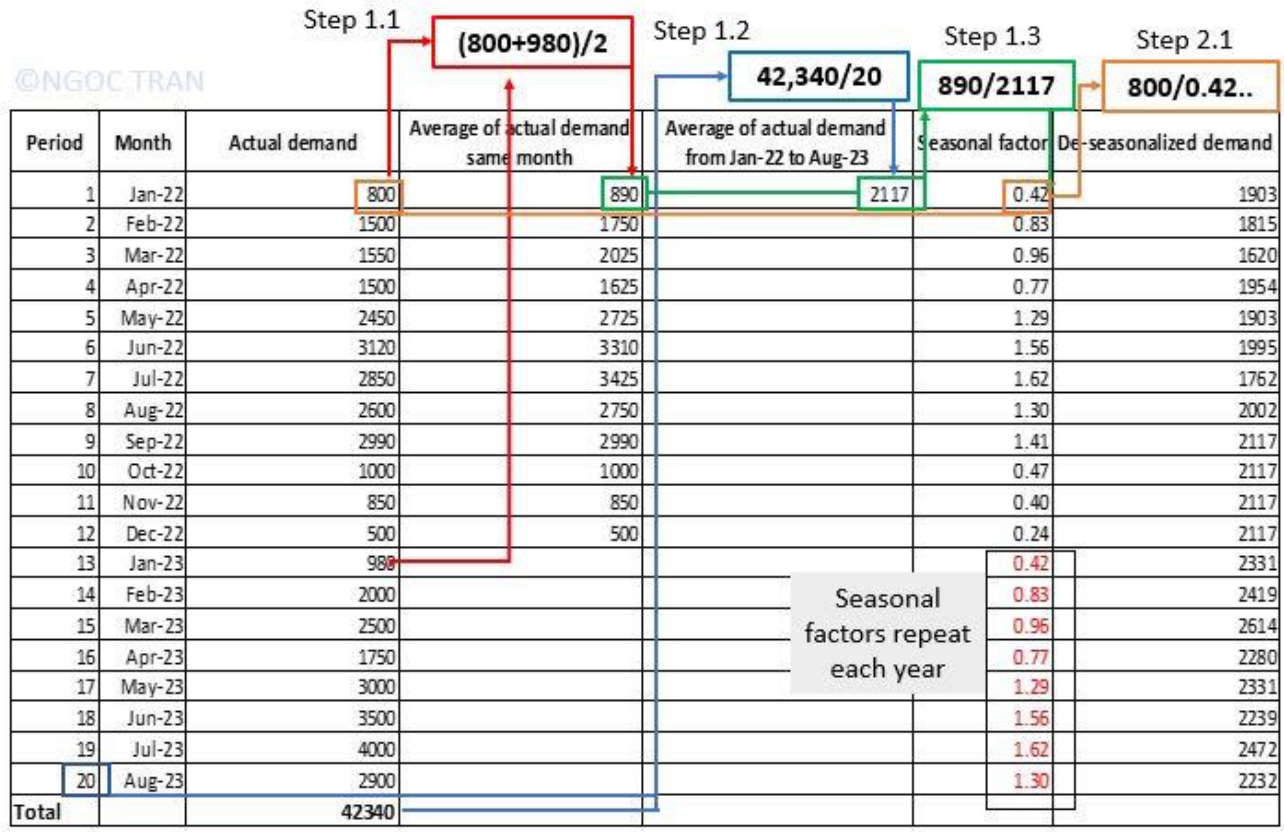
Calculate forecast demand per specific period (e.g., per month).

The formula is **(y= a + bx) * seasonal factor**, where y = a + bx is the linear regression and x is the period number (see an example of period numbers in Figure 1).

Example: If you have y = 20 + 10x and seasonal factor is 0.5, then the forecast in period x = 10 is calculated as y = (20 + 10*10)*0.5 = 60

Let's look at the example below to see how the seasonal trend forecast can be calculated. The example shows the actual demand per month from 2022 to 2023 for company A. The goal is to prepare a forecast for next year.

To find the seasonal factor, we first need to determine the average actual demand per month. The example shows data for two years, so the average actual demand per month is the sum of actual demand for Month X/2022 and Month X/2023 divided by the number of months. For example, the average actual demand of January = (800 + 980)/2. The same calculation applies to the rest of the data. Then, we calculate the average total actual demand in two years, which is the sum of actual demand in all periods divided by the number of periods (in this case, 20 periods). Following the last formula in step 1, we obtain the seasonal factor (e.g., seasonal factor for January = 890/2117). Please refer to Figure 2 (steps 1.1 to 1.3) for all calculations.



Period	Month	Actual demand	Average of actual demand same month	Average of actual demand from Jan-22 to Aug-23	Seasonal factor	De-seasonalized demand
1	Jan-22	800	890	2117	0.42	1903
2	Feb-22	1500	1750		0.83	1815
3	Mar-22	1550	2025		0.96	1620
4	Apr-22	1500	1625		0.77	1954
5	May-22	2450	2725		1.29	1903
6	Jun-22	3120	3310		1.56	1995
7	Jul-22	2850	3425		1.62	1762
8	Aug-22	2600	2750		1.30	2002
9	Sep-22	2990	2990		1.41	2117
10	Oct-22	1000	1000		0.47	2117
11	Nov-22	850	850		0.40	2117
12	Dec-22	500	500		0.24	2117
13	Jan-23	980			0.42	2331
14	Feb-23	2000			0.83	2419
15	Mar-23	2500			0.96	2614
16	Apr-23	1750			0.77	2280
17	May-23	3000			1.29	2331
18	Jun-23	3500			1.56	2239
19	Jul-23	4000			1.62	2472
20	Aug-23	2900			1.30	2232
Total		42340				

Figure 2. Calculations based on the example (made by the author)

Moving to step 2, we take the average actual demand per month divided by the corresponding seasonal factor. Please refer to step 2.1 in Figure 2. The results are de-seasonalized actual demand, which we will use to create a simple linear regression. In Excel, select the data and insert chart type X Y (Scatter), and right-click in the chart to choose “Add Trendline”. By right-clicking on the trend line and selecting “Format Trendline”, scroll down and select “Display Equation on chart”. Now, you have the equation of the data trend, which is $y = 35.765x + 1741.5$.

Finally, we create a de-seasonalized trend forecast for the coming year. Since x in the equation is the number of a period, you need to continue counting the period number of the coming months. For instance, actual demand stops at 20, so the period number is 21 for Sep 2023, 22 for Oct 2023, and so on. Then, we multiply the forecast per period with the corresponding seasonal factor. Figure 3 displays the forecast for next year.

Period	De-seasonalized demand
1	1903
2	1815
3	1620
4	1954
5	1903
6	1995
7	1762
8	2002
9	2117
10	2117
11	2117
12	2117
13	2331
14	2419
15	2614
16	2280
17	2331
18	2239
19	2472
20	2232

Seasonal trend forecast Sep 23 to Sep 24

Period	Month	Forecast from regression trend line	Seasonal factor	Re-seasonalizing trend forecast
21	Sep-23	2493	1.41	3520
22	Oct-23	2528	0.47	1194
23	Nov-23	2564	0.40	1030
24	Dec-23	2600	0.24	614
25	Jan-24	2636	0.42	1108
26	Feb-24	2671	0.83	2208
27	Mar-24	2707	0.96	2590
28	Apr-24	2743	0.77	2105
29	May-24	2779	1.29	3577
30	Jun-24	2814	1.56	4400
31	Jul-24	2850	1.62	4611
32	Aug-24	2886	1.30	3749
33	Sep-24	2922	1.41	4127

Figure 3. Seasonal trend forecast for next year based on historical data from the example

13. Compute the average seasonal movement for the following series

year	Quarterly Production			
	I	II	III	IV
2002	3.5	3.8	3.7	3.5
2003	3.6	4.2	3.4	4.1
2004	3.4	3.9	3.7	4.2
2005	4.2	4.5	3.8	4.4
2006	3.9	4.4	4.2	4.6

14. The following figures relates to the profits of a commercial concern for 8 years

Year	1986	1987	1988	1989	1990	1991	1992	1993
Profit (₹)	15,420	15,470	15,520	21,020	26,500	31,950	35,600	34,900

Find the trend of profits by the method of three yearly moving averages.

15. Find the trend of production by the method of a five-yearly period of moving average for the following data:

Year	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Production('000)	126	123	117	128	125	124	130	114	122	129	118	123

16. The following table gives the number of small-scale units registered with the Directorate of Industries between 1985 and 1991. Show the growth on a trend line by the free hand method.

Year	1985	1986	1987	1988	1989	1990	1991	1992
No. of units (in'000)	10	22	36	62	55	40	34	50

17. The annual production of a commodity is given as follows :

Year	1995	1996	1997	1998	1999	2000	2001
Production (in tones)	155	162	171	182	158	180	178

Fit a straight line trend by the method of least squares. Find the production requirement for year 2002.

The least-squares regression line equation has two common forms: y = mx + c. In a least-squares regression for y = mx + c,

$m = (N \sum (x y) - \sum x \sum y) / [(N \sum (x^2)) - (\sum x)^2]$

and

$c = (\sum y) - m \sum x / N$,

where N is the number of data points, while x and y are the coordinates of the data points.

m=3.285

c= 169.428

18. Determine the equation of a straight line which best fits the following data

Year	2000	2001	2002	2003	2004
Sales (₹ '000)	35	36	79	80	40

Compute the trend values for all years from 2000 to 2004

19. The sales of a commodity in tones varied from January 2010 to December 2010 as follows:

in year 2010	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Sales (in tones)	280	240	270	300	280	290	210	200	230	200	230	210

Fit a trend line by the method of semi-average.

20. Use the method of monthly averages to find the monthly indices for the following data of production of a commodity for the years 2002, 2003 and 2004.

2002	15	18	17	19	16	20	21	18	17	15	14	18
2003	20	18	16	13	12	15	22	16	18	20	17	15
2004	18	25	21	11	14	16	19	20	17	16	18	20

21. Calculate the seasonal indices from the following data using the average from the following data using the average method:

	I Quarterly	II Quarterly	III Quarterly	IV Quarterly
2008	72	68	62	76
2009	78	74	78	72
2010	74	70	72	76
2011	76	74	74	72
2012	72	72	76	68

22. The following table shows the number of salesmen working for a certain concern:

Year	1992	1993	1994	1995	1996
No. of salesmen	46	48	42	56	52

Use the method of least squares to fit a straight line and estimate the number of salesmen in 1997.

Answers below

Exercise 9.1

13. Seasonal Indices

	I	II	III	IV
Total	18.6	20.8	18.8	20.8
Average	3.72	4.16	3.76	4.16
Seasonal indices	94.1772	105.3165	95.1899	105.3165

The Grand Average = 3.95

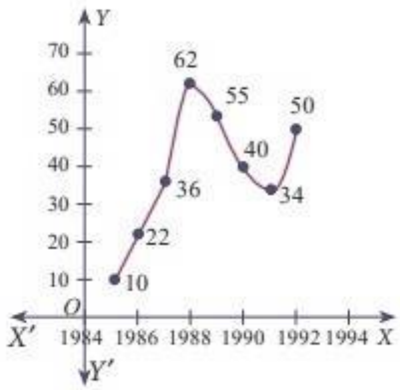
14. Three yearly moving average

Year	1987	1988	1989	1990	1991	1992
Three yearly moving total	46410	52010	63040	79470	94050	102450
Three yearly moving average	15470	17336.666	21013.333	26490	31350	34150

15. Five yearly moving average

Year	1981	1982	1983	1984	1985	1986	1987	1988
Four yearly moving total	619	617	624	621	615	619	613	606
Four yearly moving average	123.8	123.4	124.8	124.2	123	123.8	122.6	121.2

16. Free hand method



17. $a = 169.428$; $b = 3.285$; $Y = 169.428 + 3.285\ X$

18. $a = 54$; $b = 5.4$; $Y = 54 + 5.4\ X$

When $X = 2000$, $\hat{Y} = 54 + 5.4\ (2000\text{-}2002) = 43.2$

When $X = 2001$, $\hat{Y} = 54 + 5.4\ (2001\text{-}2002) = 48.6$

When $X = 2002$, $\hat{Y} = 54 + 5.4\ (2002\text{-}2002) = 54$

When $X = 2003$, $\hat{Y} = 54 + 5.4\ (2003\text{-}2002) = 59.4$

When $X = 2004$, $\hat{Y} = 54 + 5.4\ (2004\text{-}2002) = 64.8$

20. Monthly Indices

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec
Monthly Total	53	61	54	43	42	51	62	54	52	51	49	67
Monthly Average	17.6	20.3	18	14.3	14	17	20.6	18	17.3	17	16.3	22.3
Seasonal Indices	99.4	114.5	101.4	80.7	78.8	97.1	116.4	101.4	97.6	95.7	92	125.8

Grand Average = 17.74

21.

	I	II	III	IV
Total	372	358	362	364
Average	74.4	71.6	72.4	72.8
Seasonal indices	102.19	98.35	99.45	100

Grand Average = 72.8

22. $a = 46.8$; $b = 3$; $Y = 46.8 + 3X$

When $X = 1992$, $\hat{Y} = 46.8 + 3\,(1992\text{-}1994) = 40.8$

When $X = 1993$, $\hat{Y} = 46.8 + 3\,(1993\text{-}1994) = 43.8$

When $X = 1994$, $\hat{Y} = 46.8 + 3\,(1994\text{-}1994) = 46.8$

When $X = 1995$, $\hat{Y} = 46.8 + 3\,(1995\text{-}1994) = 49.8$

When $X = 1996$, $\hat{Y} = 46.8 + 3\,(1996\text{-}1994) = 52.8$

When $X = 1997$, $\hat{Y} = 46.8 + 3\,(1997\text{-}1994) = 55.8$

Ex 20: for the data as shown below find the least square fit line .

x	**1**	**2**	**3**	**4**	**5**
y	**2**	**5**	**3**	**8**	**7**

Find y for x=6

Solution: We will follow the steps to find the linear line.

x	**y**	**xy**	**x^2**
1	2	2	1
2	5	10	4
3	3	9	9
4	8	32	16
5	7	35	25
$\sum x = 15$	$\sum y = 25$	$\sum xy = 88$	$\sum x^2 = 55$

Find the value of m by using the formula,

$m = (n\sum xy - \sum y\sum x)/[n\sum x^2 - (\sum x)^2]$

$m = [(5\times 88) - (15\times 25)]/[(5\times 55) - (15)^2]$

$m = (440 - 375)/(275 - 225)$

$m = 65/50 = 13/10= 1.3$

Find the value of b by using the formula,

$c = (\sum y - m\sum x)/n$

$c = (25 - 1.3\times 15)/5$

$c = (25 - 19.5)/5$

$c = 5.5/5 = 1.1$

So, the required equation of least squares is $y = mx + c = 1.3x + 1.1$