National Cheng Kung University
Institute of International Management

Business Decision Methods

FORECASTING THE DEMAND OF INFLUENZA VACCINES AND SOLVING TRANSPORTATION PROBLEM USING LINEAR PROGRAMMING

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January, 2017

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1. Problem formulation:

1.1. Purpose of research:

Influenza is a serious disease that can lead to hospitalization and sometimes even death. Every flu season is different, and influenza infection can affect people differently, but millions of people get the flu every year, hundreds of thousands of people are hospitalized and thousands or tens of thousands of people die from flu-related causes every year. Even healthy people can get very sick from the flu and spread it to others.

Influenza, which is also known as "flu", is a disease that is infectious by an influenza virus. Its symptoms range from mild to severe levels and usually include a high fever, fatigue, sore throat, runny nose, headache, coughing, muscle pains, and headache. The symptoms usually show up two days after being affected by the virus and mostly would last several days to a week. However, the cough is very likely to last for weeks. Influenza may cause different complications like pneumonia, sinus infections, and making previous health problems even worse, such fatigue problem and asthma.

There are three types of influenza viruses that are contagious to human beings - Type A, Type B, and Type C. The virus can be spread through the air from people's sneezes or coughs. A person with influenza virus may be contagious to the other people before and during the time their symptoms are showing up.

Influenza is a major infectious disease in the winter in Taiwan. As the only and the most significant governmental unit of the disease control in Taiwan, Center of Disease Center (C.D.C.), needs to forecast the upcoming diseases on a yearly basis. Out of question, forecasting the seasonal trend of influenza is one of the most important tasks C.D.C. has been paying attention to.

As the overall influenza morbidity rates have been becoming higher, introducing influenza vaccination to citizens in Taiwan is considered the most effective way to prevent catastrophic local disease spread. However, the capacity of supply of influenza vaccines is limited. According to C.D.C, they have been consistently facing problems like how to minimize the cost of delivering the vaccines from several vaccine centers to 5 different regions which have the highest infection rates. Even the capacities of vaccines for these cities are enough, the vaccine themselves are still very fragile biologics and the low-temperature transportation is needed, which makes the transportation costs relatively expensive.

Our research consists two problems of influenza vaccine demands and supplies. Firstly, we would try to find out **how to forecast the demand of seasonal influenza vaccines, the trend, the seasonal forecast of influenza in Taiwan**. Secondly, we would **apply the forecast results in solving the transportation problem**. As the Taiwan government and citizens are assumed to bear the societal and healthcare costs, we expect that our study can provide some ideas about how to maximize the cost-effectiveness by introducing the forecast results and their planning of inventory buildup of influenza vaccines.

1.2. Research objectives:

1. Forecast the number of influenza cases by using Time-series methods.
2. Find out the optimal solution for the transportation problem the C.D.C is facing by using linear programming.

1.3. Assumptions:

1. Each source has a fixed supply of vaccines, where this entire supply must be distributed to the destinations.
2. Each destination has a fixed demand for vaccines, where this entire demand must be received from the sources.
3. The transportation cost is stable and provided by C.D.C.
4. All answers or variables are nonnegative. Negative values of physical quantities are impossible;
5. The number in the objective and constraints are known with certainty and do not change during the period being studied.

2. Procedure/ Methods:

For this study, we will focus on two issues:

1. Forecasting of vaccination for the next year 2017.
2. Finding the optimal solution for transportation problem.

2.1 Solution approaches / statistical methods:

This study will collect the past 5-year data for the number of influenza cases happened in Taiwan. The source of this data is from Centers for Disease Control (C.D.C.) Taiwan. The data is the monthly basis and we will use it to analyze the trend and the seasonal variances using the Center Moving Average (CMA) and Decomposition method from Excel QM to forecast the number of influenza cases in 2017. By knowing the forecasting number of cases, C.D.C. is able to predict the demand for the influenza vaccines in 2017.

For the second issue, we will focus on how C.D.C. will distribute the vaccines to each city in Taiwan. However, we will only focus on the top 5 cities that have the most number of influenza cases. Transportation cost per unit is collected from C.D.C. also and denominated in US$ per unit. The objective is to find the optimal number of vaccines need to be transported from C.D.C warehouses, so the total transportation cost can be minimized. Considering the limitations or constraints of the capacity for each warehouse and the demand of each city that needs to be fulfilled, we use linear programming, especially the Vogel Approximation Method from QM Software to solve the issue and find the optimal solution.

2.2. Systematic problem-solving flowchart:

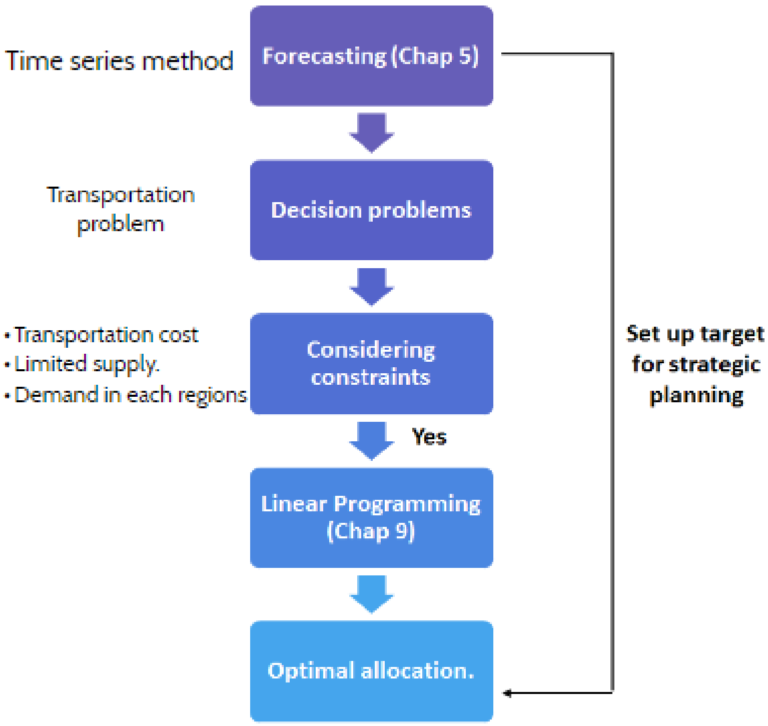


Figure 2.1: Systematic problem-solving chart.

Step 1: We will use the time-series forecasting method to forecast the demand of vaccines in 2017, the seasonal peaks, and the trend component.

Step 2: Because of limited vaccines supply, C.D.C. prioritizes the vaccines for the 5 big cities which have the highest rate of infection. The problem they face is how to minimize the cost of transporting the vaccines from several laboratories to 5 regions which have the highest rate of infection but still provide enough vaccines for these cities.

Step 3: The constraints in this research are:

- Limited vaccine supply.
- High demands at 5 big regions.
- High transportation cost.

Step 4: We will apply Linear Programming to solve this transportation problem C.D.C. is facing. The transportation problem deals with the distribution of vaccine from several points of supply (origins or sources) to a number of points of demand (5 big cities). We are given a capacity (supply) of vaccines at each source, and we will forecast the requirement (demand) for vaccines at each city in 2017 at step 1, and the shipping cost per unit from each source to each destination will be provided by the C.D.C.

Step 5: After applying LP method to find out the results, we will come up with the optimal solution.

2.3. Technical and programming difficulties:

For this study, the data of patient of influenza is obtained from C.D.C. since January 2012 to December 2016 in Taiwan. Influenza demand forecasting plays an important role in short-term vaccines allocation and long-term planning for transportation. It is a challenging problem because of the different uncertainties including underlying population growth, weather conditions. The most challenging part is that we often want to forecast the peak demand rather than the average demand. Because of numerous historical data, the calculation becomes very complex.

For the transportation problem, the number of vaccines that are provided by the government (C.D.C.) to every region. However, in this study, we only consider the constraints for demand in 5 cities with the highest number of cases. In other words, the optimal solution derived from the software might be different if we included the demand constraints from other cities.

3. Analysis of results:

3.1. Forecast the demands:

Seasonal influenza is a serious public health problem that causes severe illness and death in high-risk populations. As fall approaches and the weather gets colder, the influenza season is upon us. Seasonal influenza in Taiwan often goes peak during winter. Therefore, the historical data has a relation to the future forecast. If the historical data are restricted to past values of the variable to be forecast, the forecasting procedure is called a time series method and the historical data are referred to as a time series. The objective of time series analysis is to discover a pattern in the historical data or time series and then extrapolate the pattern into the future; the forecast is based solely on past values of the variable and/or on past forecast errors.

Year	Month											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012	1018	536	321	194	210	316	339	151	66	74	70	70
2013	128	167	237	340	270	197	104	80	89	89	110	184
2014	709	866	594	303	224	182	172	61	73	63	50	62
2015	129	177	222	195	224	276	124	82	75	42	64	107
2016	354	1450	952	230	97	56	54	43	64	141	249	134

Table 3.1: Number of cases influenza, nationwide, indigenous and imported (Thousand)

Source: Center for Disease Control (Taiwan).

3.1.1. Trend Projections:

This technique fits a trend line to a series of historical data points and then projects the line into the future for medium - to long-range forecasts. A trend line is simply a linear regression equation in which the independent variable (X) is the time period. The form here is Y = 278.39 – 1.33X.

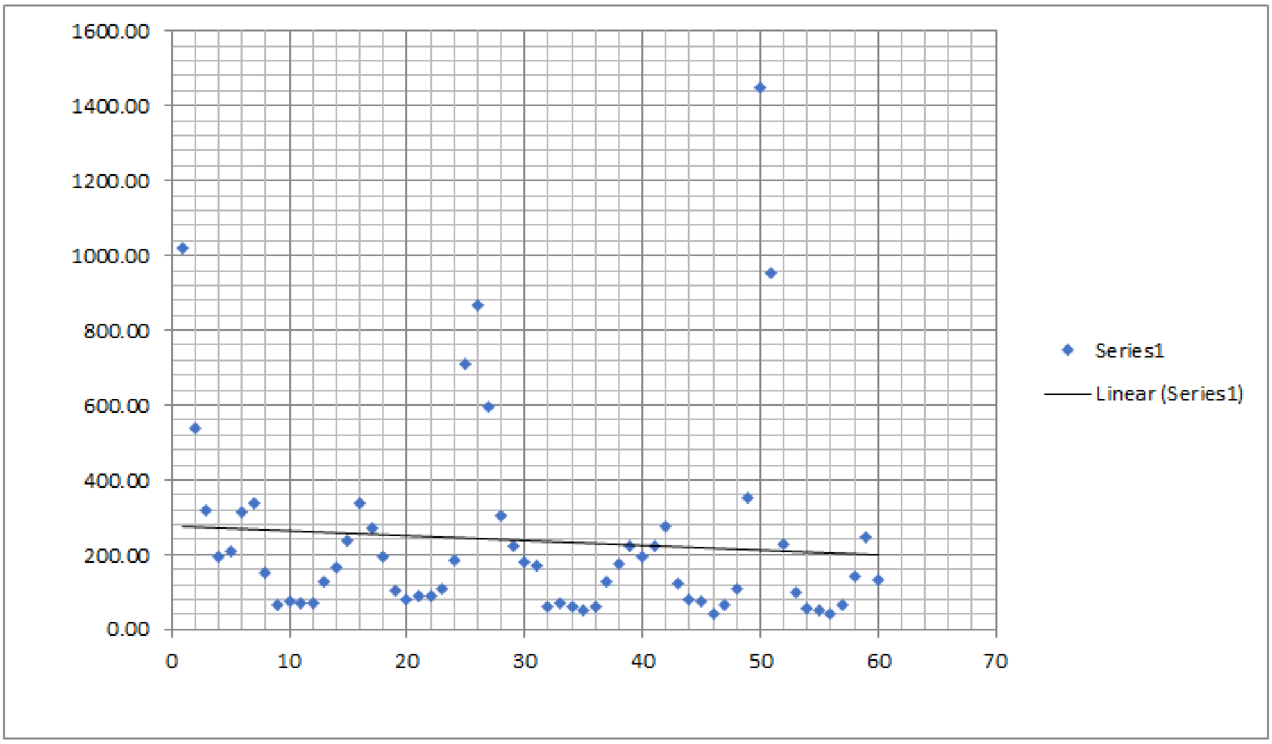


Figure 3.1: Taiwan Influenza and the Computed Trend Line.

A trend is usually the result of long-term factors such as population increases or decreases, changing demographic characteristics of the population, technology, and/or consumer preferences. From the figure, we can see that the trend for the influenza cases time series in the past appeared to be decreasing over time. However, the trend here is not significant because the slope is not high.

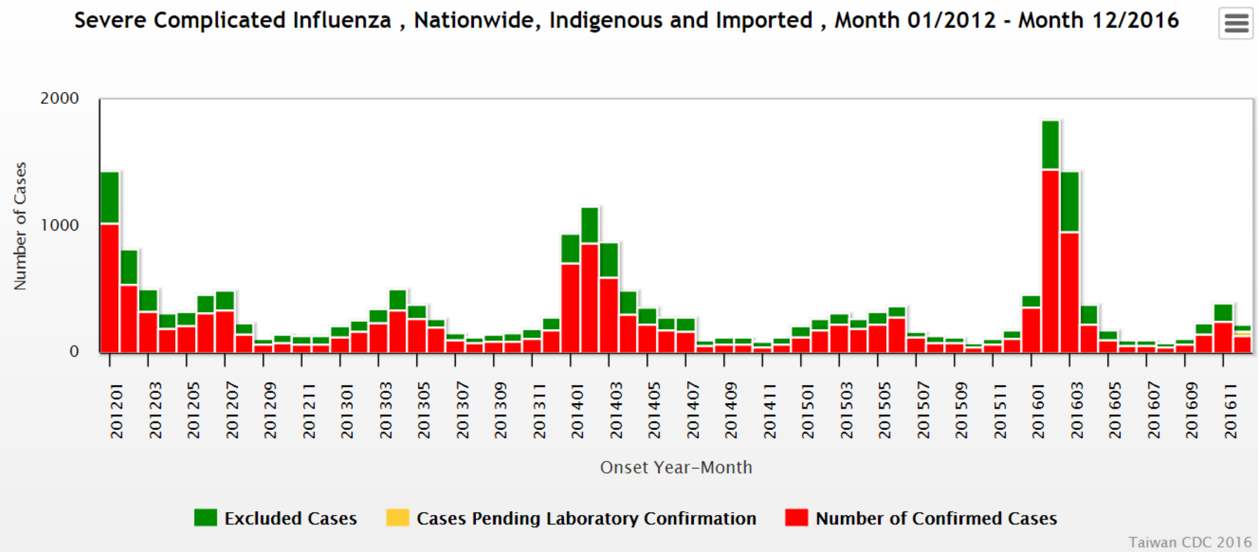


Figure 3.2: Influenza Cases, Nationwide, Indigenous, and Imported, from 2012 to 2016.

Source: Taiwan National Infectious Disease Statistics System

According to the statistics compiled by Taiwan CDC, in the past, the number of severe influenza complications reached its peak from January to March and continue to March.

3.1.2. Seasonal Variation with Trends:

When both trend and seasonal components are present in a time series, a change from one month to the next could be due to a trend, to a seasonal variation, or simply to random fluctuations.

To help with this problem, the seasonal indices should be computed using a **centered moving average (CMA)** approach whenever trend is present. Using this approach prevents a variation due to trend from being incorrectly interpreted as a variation due to the season. The results are showed as below:

	2012	2013	2014	2015	2016
Jan		165.958	297.333	140.000	299.833
Feb		153.208	299.375	138.875	295.292
Mar		151.208	297.917	139.833	293.208
Apr		152.792	296.167	139.042	296.875
May		155.083	292.583	138.750	308.708
Jun		161.500	285.000	141.208	317.542
Jul	243.333	190.458	255.750	152.458	
Aug	190.875	243.792	202.875	214.875	
Sep	172.000	287.792	158.667	298.333	
Oct	174.583	301.125	138.667	330.208	
Noc	183.167	297.667	134.167	326.375	
Dec	180.708	295.125	138.083	311.917	

Table 3.2: Centered Moving Averages for Influenza Cases(2012-2016).

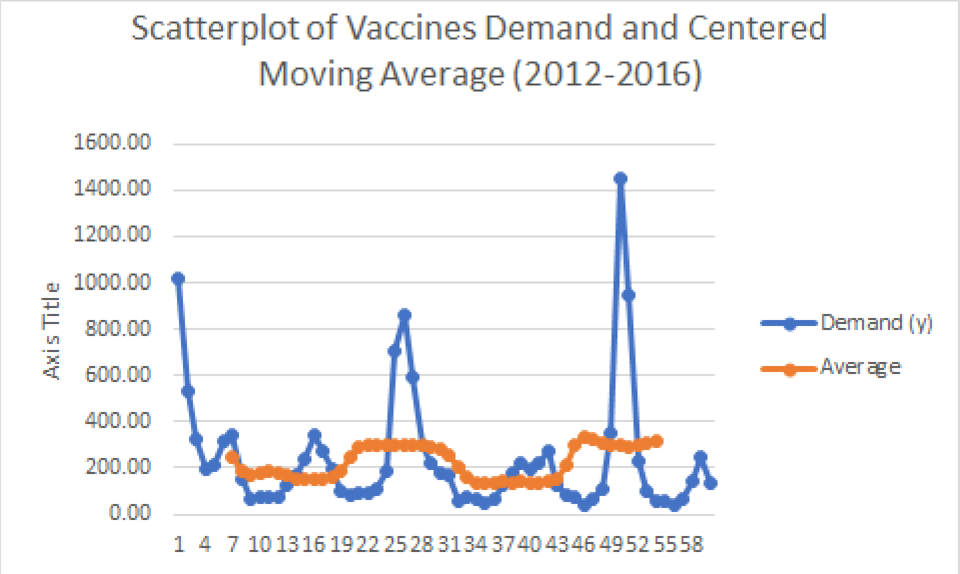


Figure 3.3: Scatterplot of Vaccines Demand and Centered Moving Average (2012-2016).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2012							1.393	0.791	0.384	0.424	0.382	0.387
2013	0.771	1.090	1.567	2.225	1.741	1.220	0.546	0.328	0.309	0.296	0.370	0.623
2014	2.385	2.893	1.994	1.023	0.766	0.639	0.673	0.301	0.460	0.454	0.373	0.449
2015	0.921	1.275	1.588	1.402	1.614	1.955	0.813	0.382	0.251	0.127	0.196	0.343
2016	1.181	4.910	3.247	0.775	0.314	0.176						
Average	1.314	2.542	2.099	1.356	1.109	0.997	0.856	0.450	0.351	0.325	0.330	0.451

Table 3.3: Seasonal Ratio for Influenza Cases.

	2012	2013	2014	2015	2016
Jan	1.314	1.314	1.314	1.314	1.314
Feb	2.542	2.542	2.542	2.542	2.542
Mar	2.099	2.099	2.099	2.099	2.099
Apr	1.356	1.356	1.356	1.356	1.356
May	1.109	1.109	1.109	1.109	1.109
Jun	0.997	0.997	0.997	0.997	0.997
Jul	0.856	0.856	0.856	0.856	0.856
Aug	0.450	0.450	0.450	0.450	0.450
Sep	0.351	0.351	0.351	0.351	0.351
Oct	0.325	0.325	0.325	0.325	0.325
Noc	0.330	0.330	0.330	0.330	0.330
Dec	0.451	0.451	0.451	0.451	0.451

Table 3.4: Seasonal Indices based on CMA for Influenza Cases

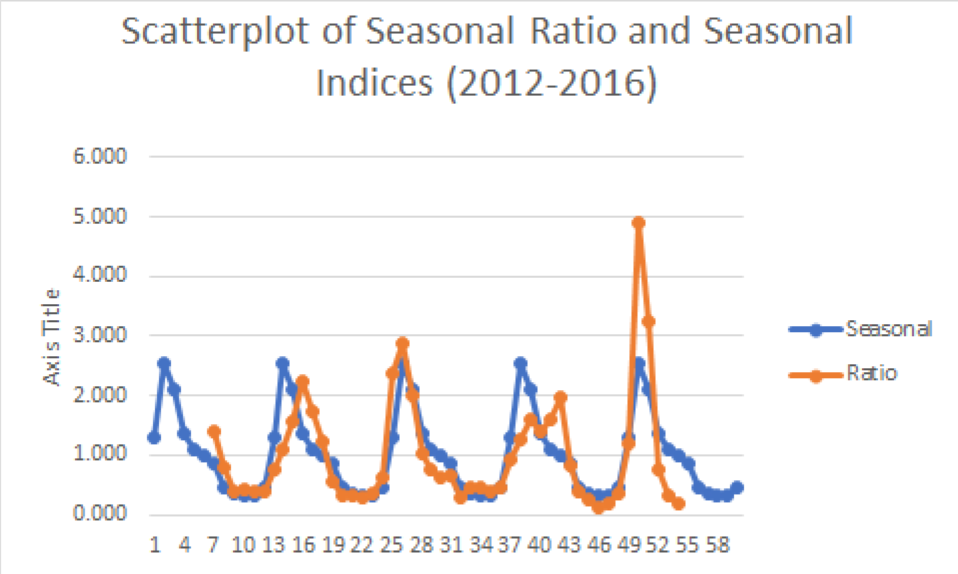


Figure 3.4: Scatterplot for Seasonal Ratio and Seasonal Indices (2012 - 2016).

3.1.3. Using Regression with Trend and Seasonal Components:

Multiple regression may be used to forecast with both trend and seasonal components present in a time series. One independent variable is time, and other independent variables are dummy variables to indicate the season. A trend line is simply a linear regression equation in which the independent variable (X) is the time period. The form in this case is: **Y = 240.48 - 0.21X.**

3.1.4. The Decomposition Method of Forecasting with Trend and Seasonal Components

The process of isolating linear trend and seasonal factors to develop more accurate forecasts is called decomposition.

Period	Month	Unadjusted	Seasonal	Adjusted
61	01-2017	228	1.314	300
62	02-2017	228	2.542	579
63	03-2017	228	2.099	478
64	04-2017	227	1.356	308
65	05-2017	227	1.109	252
66	06-2017	227	0.997	226
67	07-2017	227	0.856	194
68	08-2017	226	0.450	102
69	09-2017	226	0.351	79
70	10-2017	226	0.325	74

71	11-2017	226	0.330	75
72	12-2017	226	0.451	102

Table 3.5: The demand for vaccines in 2017 using The Decomposition Method with Trend and Seasonal Components.

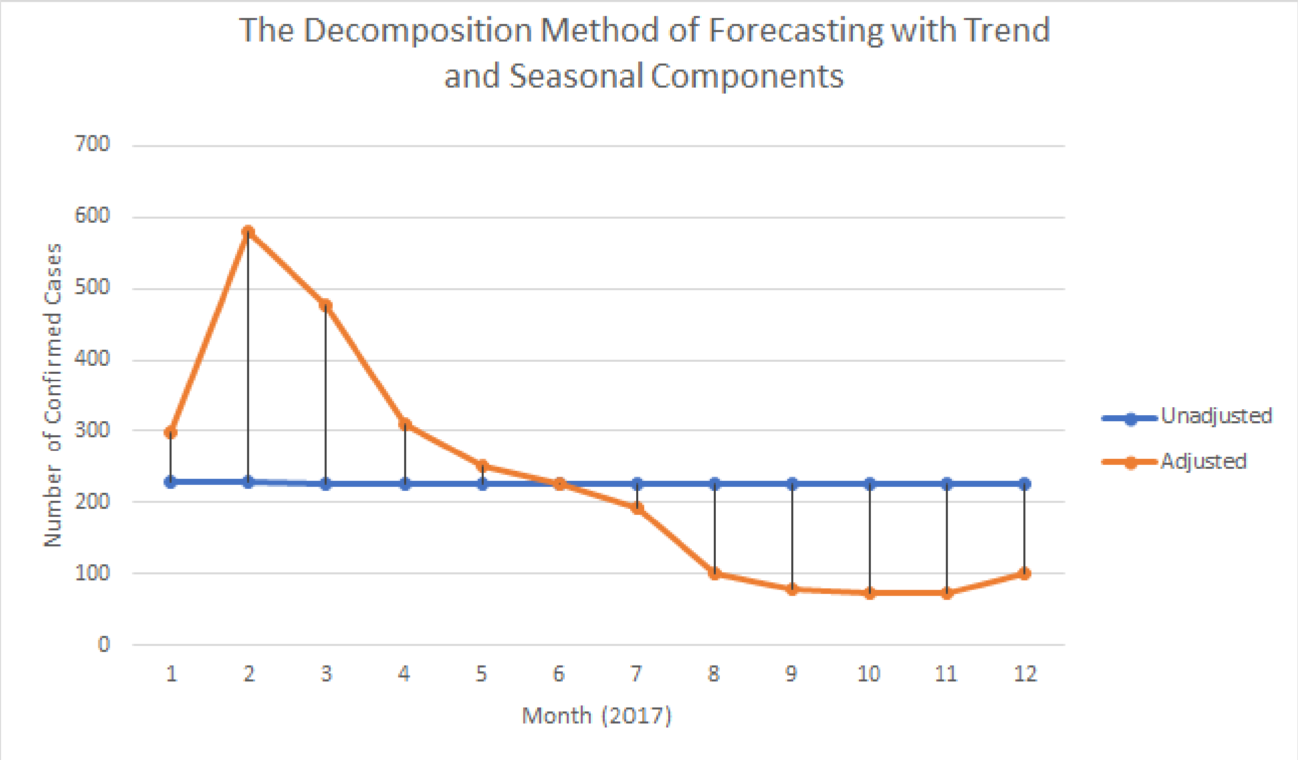


Figure 3.5: Forecasting influenza vaccines demand in 2017 using decomposition method.

In 2017, the influenza cases will increase from January to March and peak in February. This is the winter season in Taiwan. After the winter season, seasonal influenza will decrease until December. This seasonal cycle is similar to seasonal cycle in the previous year.

3.1.5. Regional demand forecast:

We also use the decomposition method to forecast the demand of 5 regions in 2017, includes Taipei - Taoyuan, Changhua, Taichung, Tainan, Kaohsiung. The results are showed in the table below:

Region	2012	2013	2014	2015	2016	2017 (Forecast)
Taipei - Taoyuan	667	498	922	234	668	519
Changhua	83	62	70	99	126	125
Taichung	67	29	59	53	190	161
Tainan	171	75	114	100	265	209
Kaohsiung	207	100	209	140	258	225

Total demand of 5 regions	1,195	764	1,374	626	1,507	1,239
Total demand of Taiwan	1,595	965	1,721	857	2,074	2,768

Table 3.6: Forecasting influenza vaccines demand in 2017 using decomposition method in 5 regions.

Source: Taiwan National Infectious Disease Statistics System

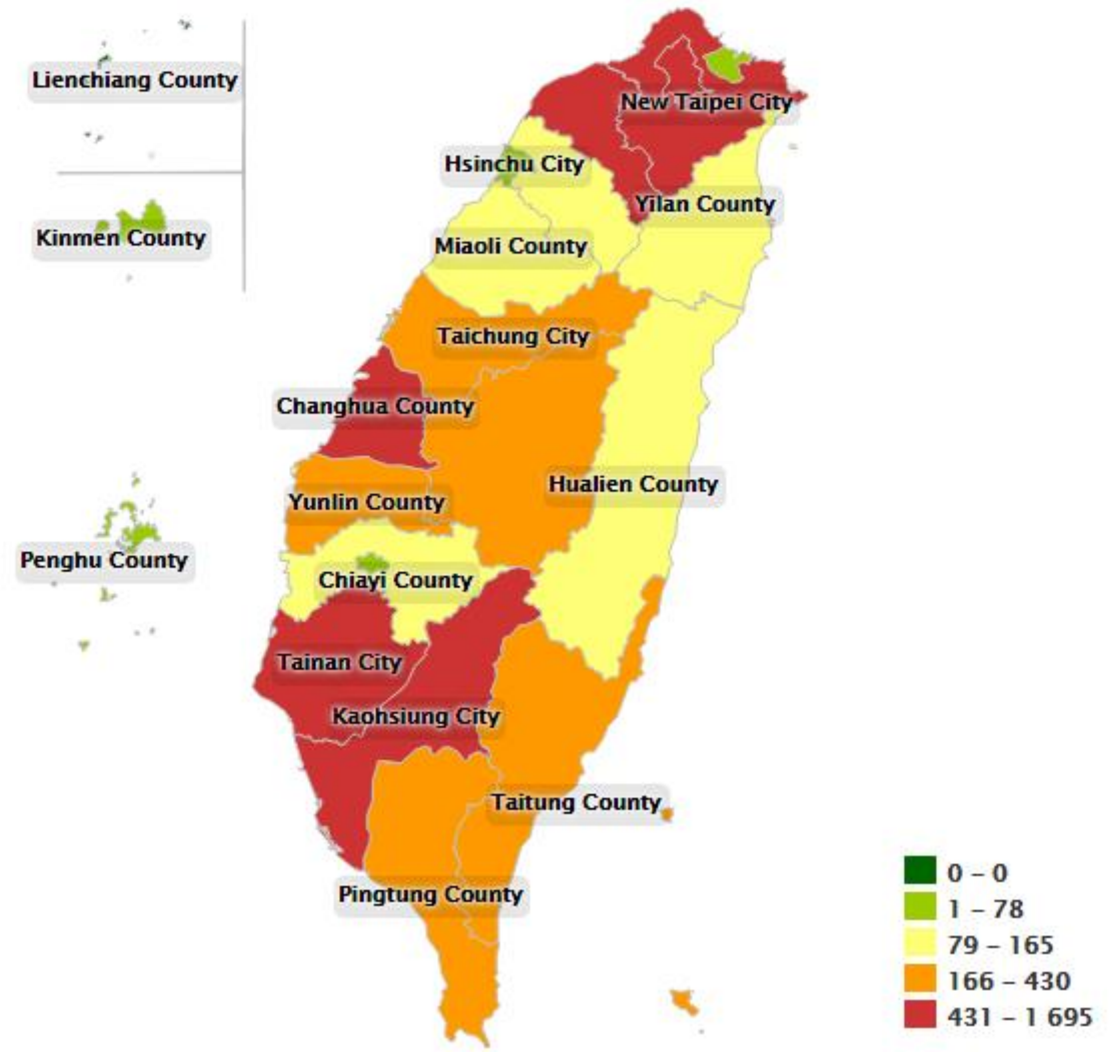


Figure 3.6: Influenza, indigenous, and imported, nationwide, 2012-2016.

Source: Taiwan National Infectious Disease Statistics System

The red regions represent the regions which have the highest infectious cases. These are Taipei – Taoyuan, Tainan, Changhua, Tainan and Kaohsiung.

3.2 Transportation Problem:

Taiwan C.D.C. currently has 3 warehouses to store the vaccines for influenza located at Hsinchu, Taipei, and Kaohsiung, Taiwan. In order to prevent the outbreak of influenza, Taiwan C.D.C. needs to distribute the vaccines from their warehouses to 5 regions which have the highest infectious rate in Taiwan, especially to the cities that have the highest cases, which are Taipei - Taoyuan, Taichung, Changhua, Tainan, and Kaohsiung.

3.2.1 The Transportation Cost Per Unit:

Below is the table of the transportation cost per unit (US Dollar) to transport the vaccines from each warehouse to the specific cities included in this research:

From	To				
	Taipei, Taoyuan	Taichung	Changhua	Tainan	Kaohsiung
Hsinchu	1.0	1.8	1.9	2.2	2.4
Taipei	0.9	1.9	2.0	2.3	2.5
Kaohsiung	2.5	2.0	1.9	1.3	0.8

Table 3.7: Transportation cost per unit from warehouse to destination cities (US$).

Source: Taiwan Centers for Disease Control.

3.2.2 The supply capacity:

The supply of the vaccines is provided by the government and will be distributed to each warehouse of CDC. The proportion of the distribution for each warehouse is as follow:

Warehouse	Capacity (in Thousands)
Hsinchu	650
Taipei	1,100
Kaohsiung	1,450
Total	3,200

Table 3.8: Distribution of C.D.C. warehouse capacity.

Source: Taiwan Centers for Disease Control

3.2.3 Linear Programming Formulation:

Using the data of transportation cost, the supply capacity, and also the forecasted demand that we already have done above, we can formulate the objective and constraints for the transportation problem. Let say:

Xij = Number of Vaccines distribute from warehouse i to cities j

i = 1, 2, 3 1 = Hsinchu 2 = Taipei 3 = Kaohsiung.

j = 1, 2, 3, 4, 5 1 = Taipei, Taoyuan 2 = Taichung 3 = Changhua 4 = Tainan 5 = Kaohsiung.

Using linear programming, the objective formulation is as follow:

Minimize total transportation cost = $1X_{11} + 1.8X_{12} + 1.9X_{13} + 2.2X_{14} + 2.4X_{15} + 0.9X_{21} + 1.9X_{22} + 2X_{23} + 2.3X_{24} + 2.5X_{25} + 2.5X_{31} + 2X_{32} + 1.9X_{33} + 1.3X_{34} + 0.8X_{35}$

For the first constraint is the supply capacity of each warehouse, which are formulated below:

- $X_{11} + X_{12} + X_{13} + X_{14} + X_{15} \le 650$ (Hsinchu supply)
- $X_{21} + X_{22} + X_{23} + X_{24} + X_{25} \le 1{,}100$ (Taipei supply)
- $X_{31} + X_{32} + X_{33} + X_{34} + X_{35} \le 1{,}450$ (Kaohsiung supply)

The second constraint is the demand that Taiwan CDC needs to fulfill, which are formulated below:

- $X_{11} + X_{21} = 519$ (Taipei, Taoyuan demand)
- $X_{12} + X_{22} = 125$ (Taichung demand)
- $X_{13} + X_{23} = 161$ (Changhua demand)
- $X_{14} + X_{24} = 209$ (Tainan demand)
- $X_{15} + X_{25} = 225$ (Kaohsiung demand)

3.2.4 Linear Programming Result:

Finding the solution using Transportation Module in QM Software specifically using Vogel Approximation Method, the result is below:

From	To					
	Taipei, Taoyuan	Taichung	Changhua	Tainan	Kaohsiung	Dummy
Hsinchu		125	161			364
Taipei	519					581
Kaohsiung				209	225	1016

Table 3.9: Optimal solution of vaccines distribution using Vogel Approximation Method.

The optimum solution is delivering:

- 125,000 units from Hsinchu to Taichung, 161,000 units from Hsinchu to Changhua;
- 519,000 units from Taipei to Taipei and Taoyuan;
- 209,000 units from Kaohsiung to Tainan, and 225,000 from Kaohsiung to within Kaohsiung.

The total cost of transportation by doing the optimal solution is as follow:

From	To	Shipment (Vaccines)	Cost / Unit	Cost (Thousand)
Hsinchu	Taichung	125	$1.8	$225.00
Hsinchu	Changhua	161	$1.9	$305.90
Taipei	Taipei - Taoyuan	519	$0.9	$467.10
Kaohsiung	Tainan	209	$1.3	$271.70
Kaohsiung	Kaohsiung	225	$0.8	$180.00
Total				$1,449.7

Table 3.10: Total transportation cost using the optimal solution.

Total transportation cost from Hsinchu to Taichung is 225,000, from Hsinchu to Changhua 305,900, from Taipei to Taipei and Taoyuan 467,100, from Kaohsiung to Tainan 271,700, from Kaohsiung to Kaohsiung 180,000. So the total cost that CDC need to pay is 1,449,700.

Since there is excess in capacity, there are dummy destinations which represent the other cities in Taiwan besides those 5 cities. From Hsinchu there are 364,000 units that can be transported, From Taipei there are 581,000 units, and 1,016,000 units from Kaohsiung.

4. Conclusion:

4.1. Specific (applications):

Annual vaccination is the most important measure to prevent seasonal influenza infection. Therefore, forecasting the number of influenza cases is certainly important for Taiwan C.D.C. Based on our result, the cases will peak in February 2017 and will decrease gradually until December 2017. It is similar to the past trend that previously happened in Taiwan. The highest number of cases are found in Taipei and Taoyuan, followed by Kaohsiung, Tainan, Changhua, and Taichung.

Knowing this result Taiwan C.D.C. can actively prepare for the flu season by distributing the vaccines through its warehouses to those cities. Considering the supply and demand and also in order to achieve the minimum transportation cost, we found that Taiwan C.D.C. should deliver from Hsinchu warehouse to Taichung and Changhua, from Taipei warehouse to Taipei and Taoyuan area, and from Kaohsiung warehouse to Tainan and Kaohsiung.

4.2. General (principles):

An annual seasonal flu vaccine is the best way to reduce the risk of getting sick with the seasonal flu and spreading it to others. When more people get vaccinated against the flu, less flu can spread through that community. Everyone 6 months of age and older should get a flu vaccine every season. This recommendation has been in place by C.D.C. of Taiwan.

Flu vaccination should begin soon after vaccine becomes available, if possible by December. However, as long as flu viruses are circulating, vaccination should continue to be offered throughout the flu season, even in March or later. While seasonal influenza outbreaks can happen as early as January, during most seasons influenza activity peaks in February or later. Since it takes about two weeks after vaccination for antibodies to develop in the body that protects against influenza virus infection, it is best that people get vaccinated so they are protected before influenza begins spreading in their community.

Flu vaccine is imported by the government, and the timing of availability depends on when the import is completed. Shipments should be made in December until all vaccine is distributed.

A flu vaccine is needed every season for two reasons. First, the body's immune response from vaccination declines over time, so an annual vaccine is needed for optimal protection. Second, because flu viruses are constantly changing, the formulation of the flu vaccine is reviewed each year and sometimes updated to keep up with changing flu viruses. For the best protection, everyone 6 months and older should get vaccinated annually. Therefore, the flu vaccines shipment should be made every year in December.

4.3. Summary for management:

Prevention is the most effective management strategy for influenza. To prevent seasonal flu, the Disease Control and Prevention (C.D.C.) of Taiwan should recommend routine annual influenza vaccination for all persons aged 6 months or older, preferably before the onset of influenza activity in the community. The onset of influenza activity will start in January and peak in February. Therefore, the C.D.C. can recommend the people to have the vaccines before the onset.

The C.D.C. should recommend the people to get the flu vaccines before the beginning of the flu season and during the flu season. The C.D.C. could launch the “Take 3” program to encourage people to get the vaccines, includes, (1) take time to get a flu vaccine; (2) take everyday preventive actions to stop the spread of germs; (3) take flu antiviral drugs if your doctor prescribes them.

Taiwan government should encourage the corporations urged to get employees vaccinated. Private companies and schools are encouraged to promote mass influenza vaccination among their employees.

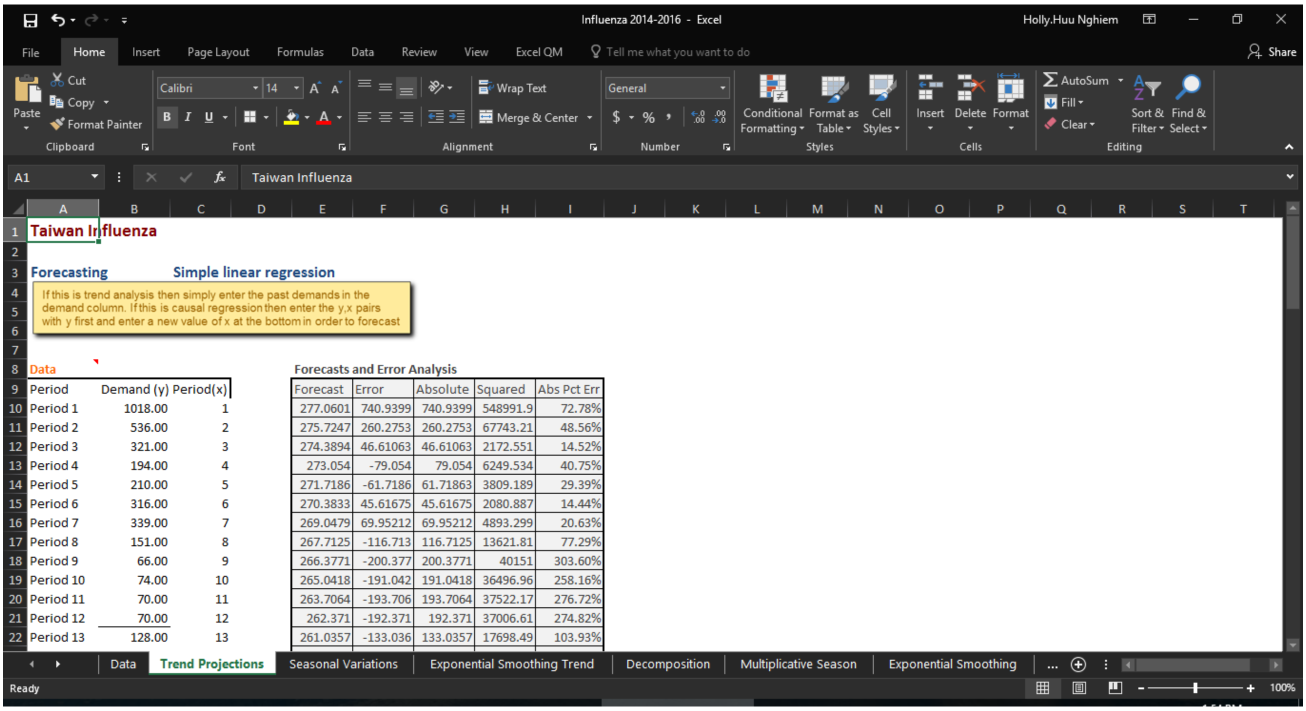
The C.D.C. should also address the use of this vaccine to the local hospitals, especially to the hospitals in Taipei, New Taipei City, Taoyuan, Changhua, Taichung, Tainan, and Kaohsiung. Our research results show that these regions have the highest infectious rate.

During influenza season (defined as periods when influenza viruses are circulating in the community), the diagnosis of influenza should be considered in the following patients, regardless of vaccination status.

5. Appendixes

5.1 Excel Forecasting Results:

5.1.1. Trend Projection results using Excel QM:



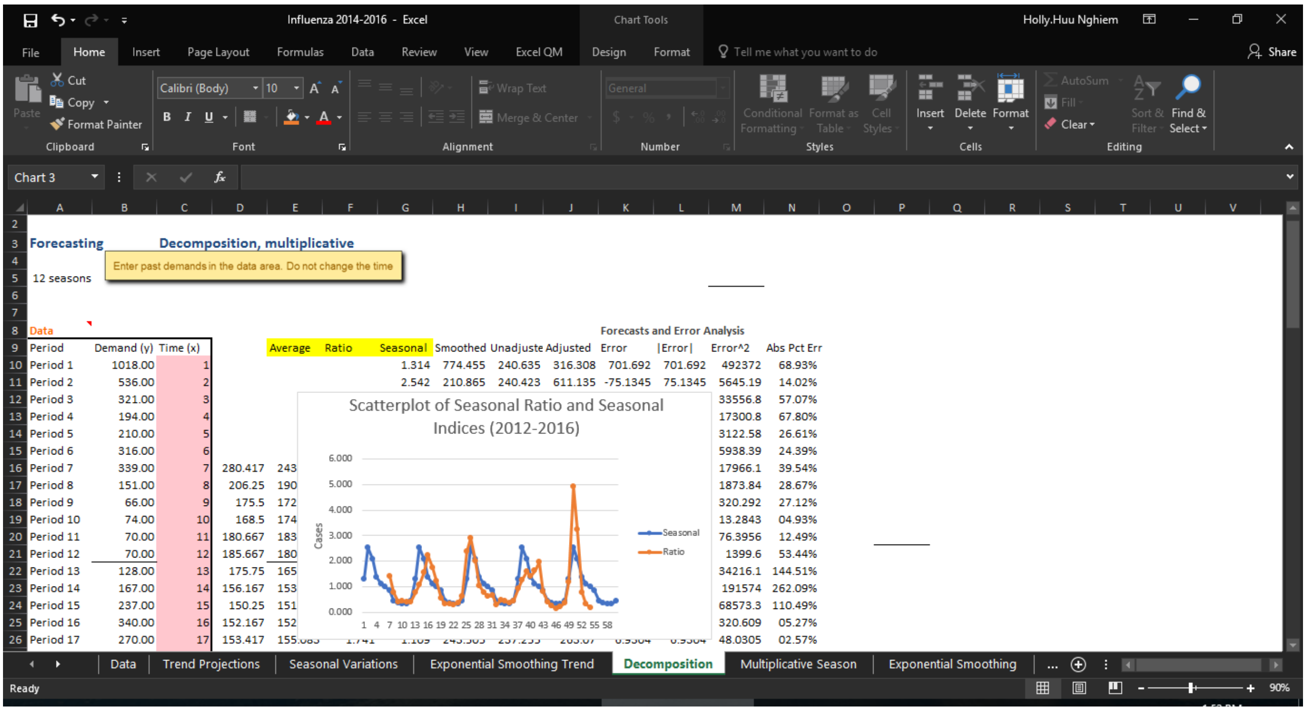
Taiwan Influenza

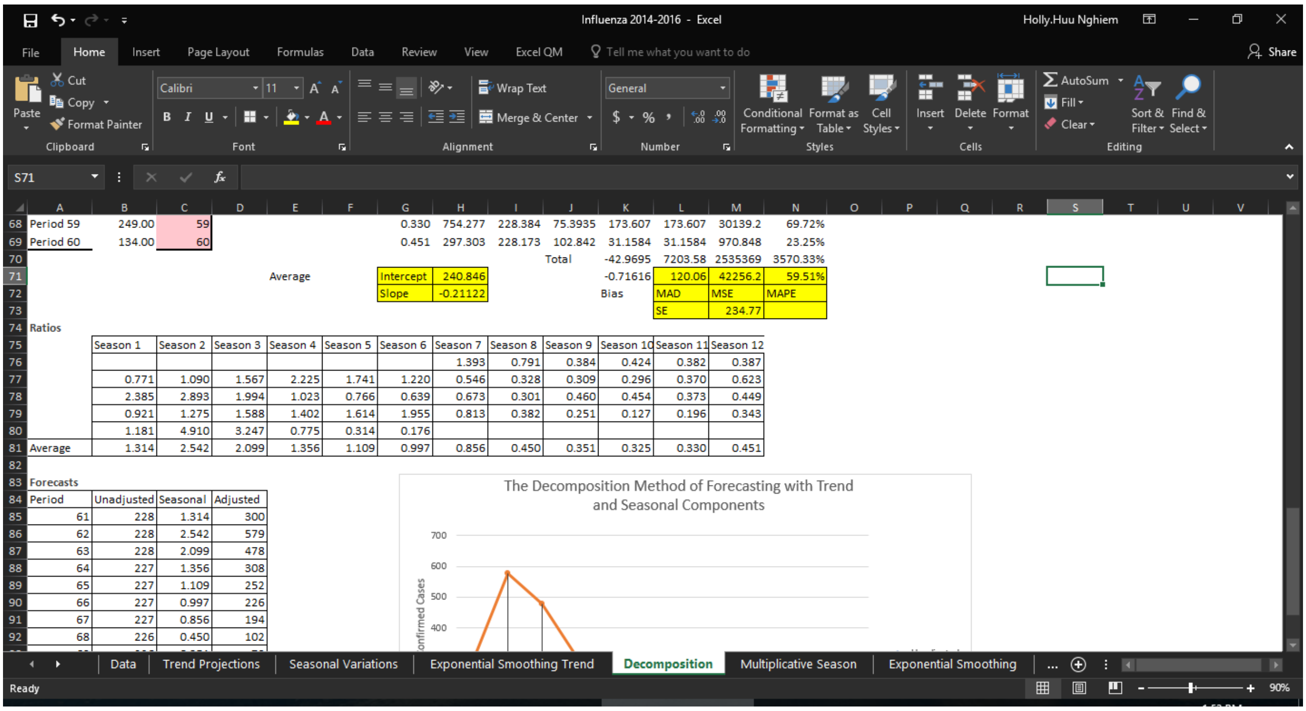
Forecasting — Simple linear regression

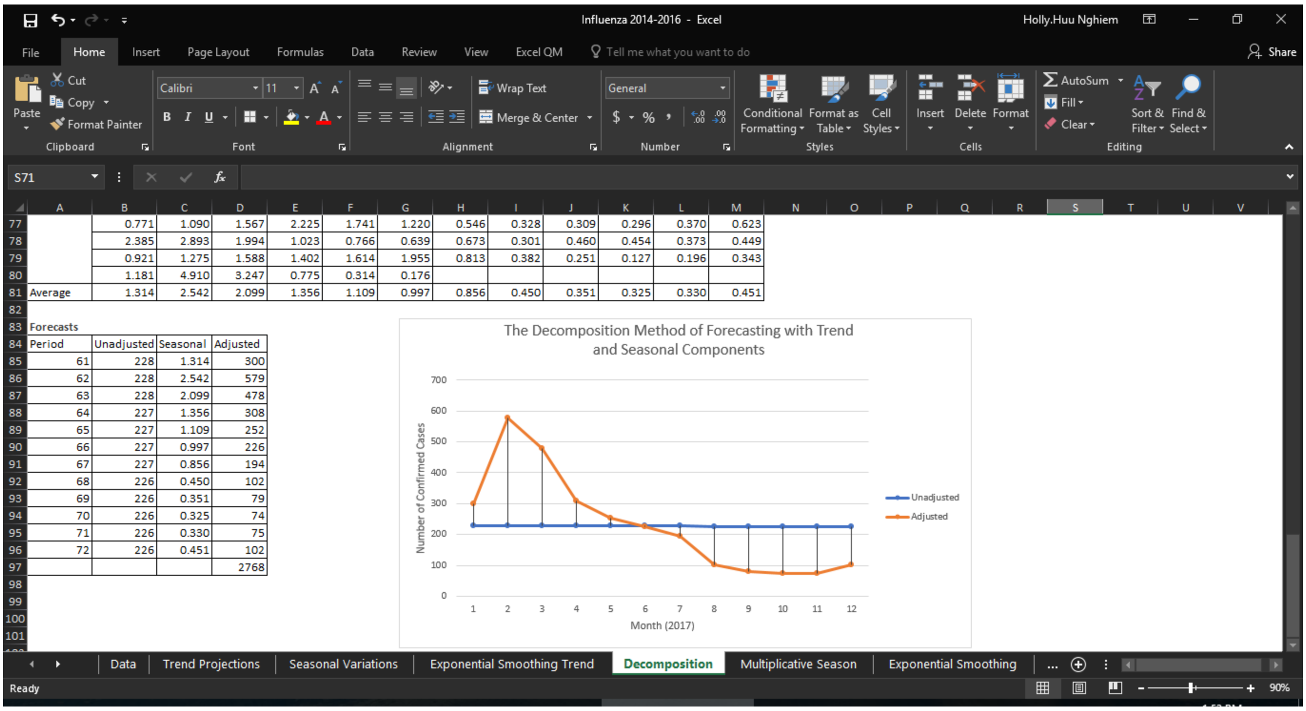
If this is trend analysis then simply enter the past demands in the demand column. If this is causal regression then enter the y,x pairs with y first and enter a new value of x at the bottom in order to forecast

Data			Forecasts and Error Analysis				
Period	Demand (y)	Period(x)	Forecast	Error	Absolute	Squared	Abs Pct Err
Period 1	1018.00	1	277.0601	740.9399	740.9399	548991.9	72.78%
Period 2	536.00	2	275.7247	260.2753	260.2753	67743.21	48.56%
Period 3	321.00	3	274.3894	46.61063	46.61063	2172.551	14.52%
Period 4	194.00	4	273.054	-79.054	79.054	6249.534	40.75%
Period 5	210.00	5	271.7186	-61.7186	61.71863	3809.189	29.39%
Period 6	316.00	6	270.3833	45.61675	45.61675	2080.887	14.44%
Period 7	339.00	7	269.0479	69.95212	69.95212	4893.299	20.63%
Period 8	151.00	8	267.7125	-116.713	116.7125	13621.81	77.29%
Period 9	66.00	9	266.3771	-200.377	200.3771	40151	303.60%
Period 10	74.00	10	265.0418	-191.042	191.0418	36496.96	258.16%
Period 11	70.00	11	263.7064	-193.706	193.7064	37522.17	276.72%
Period 12	70.00	12	262.371	-192.371	192.371	37006.61	274.82%
Period 13	128.00	13	261.0357	-133.036	133.0357	17698.49	103.93%

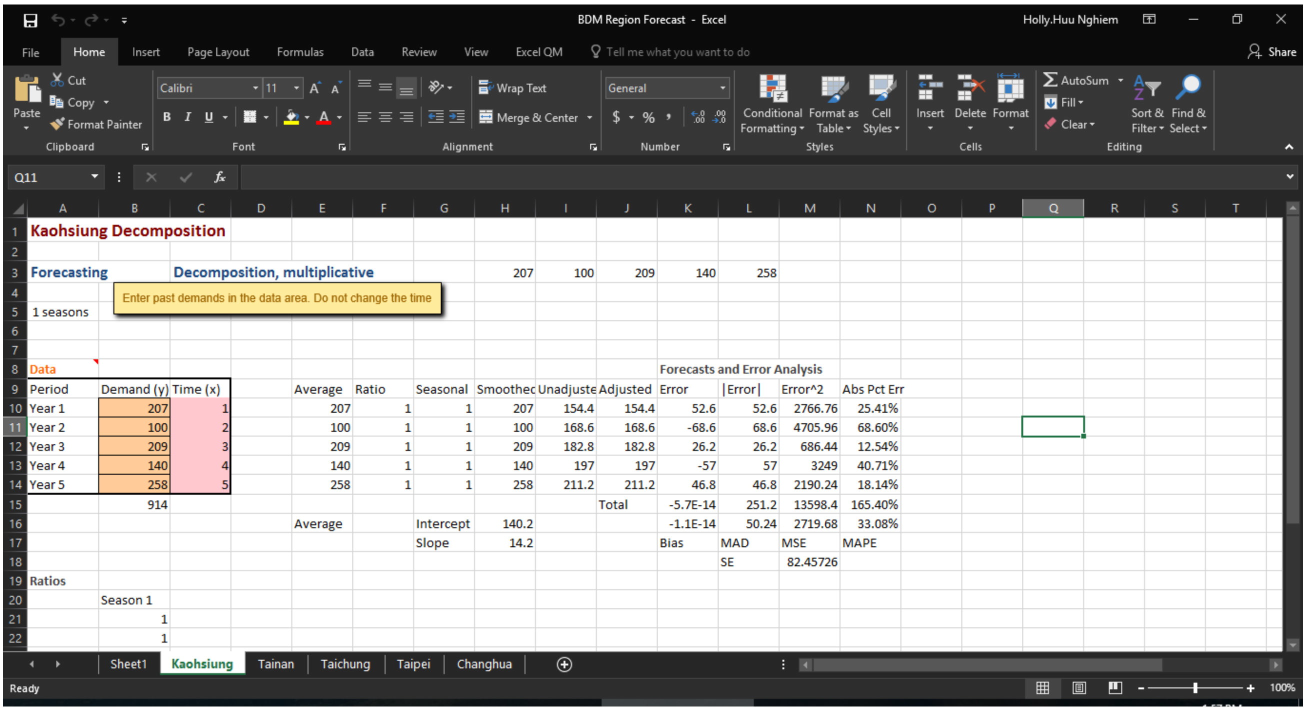
5.1.2. Decomposition results using Excel QM:







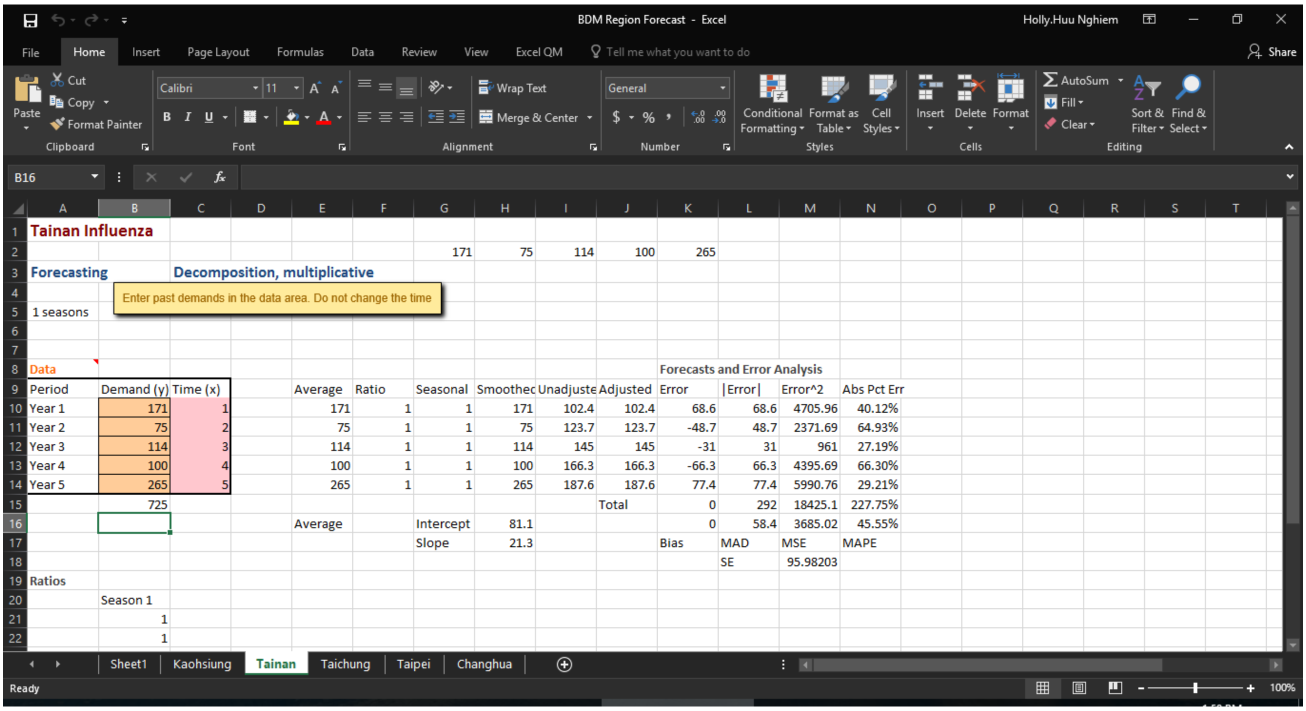
5.1.3. Regional demand forecasting using Excel QM:



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Kaohsiung Decomposition													
2														
3	Forecasting		Decomposition, multiplicative					207	100	209	140	258		
4														
5	1 seasons													
6														
7														
8	Data										Forecasts and Error Analysis			
9	Period	Demand (y)	Time (x)		Average	Ratio	Seasonal	Smoothec	Unadjuste	Adjusted	Error	|Error|	Error^2	Abs Pct Err
10	Year 1	207	1		207	1	1	207	154.4	154.4	52.6	52.6	2766.76	25.41%
11	Year 2	100	2		100	1	1	100	168.6	168.6	-68.6	68.6	4705.96	68.60%
12	Year 3	209	3		209	1	1	209	182.8	182.8	26.2	26.2	686.44	12.54%
13	Year 4	140	4		140	1	1	140	197	197	-57	57	3249	40.71%
14	Year 5	258	5		258	1	1	258	211.2	211.2	46.8	46.8	2190.24	18.14%
15		914								Total	-5.7E-14	251.2	13598.4	165.40%
16					Average		Intercept	140.2			-1.1E-14	50.24	2719.68	33.08%
17							Slope	14.2			Bias	MAD	MSE	MAPE
18												SE	82.45726	
19	Ratios													
20		Season 1												
21		1												
22		1												

Enter past demands in the data area. Do not change the time

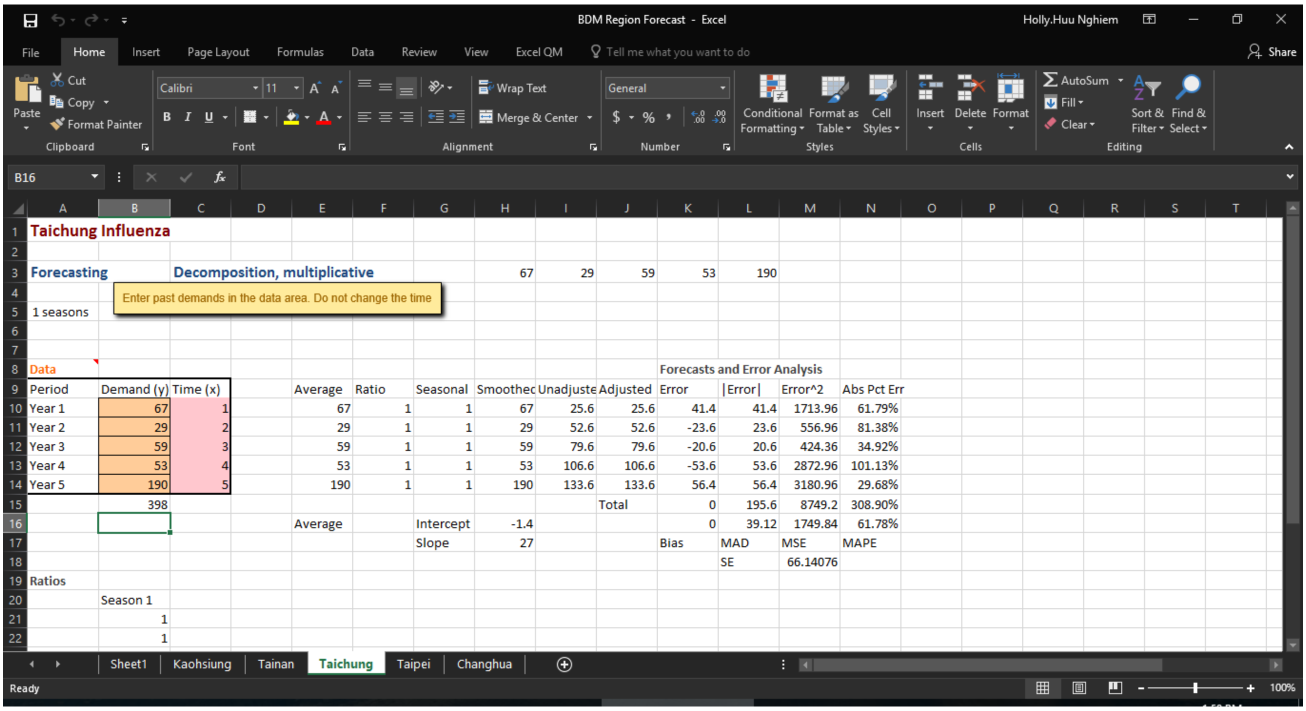
Sheet1 | Kaohsiung | Tainan | Taichung | Taipei | Changhua



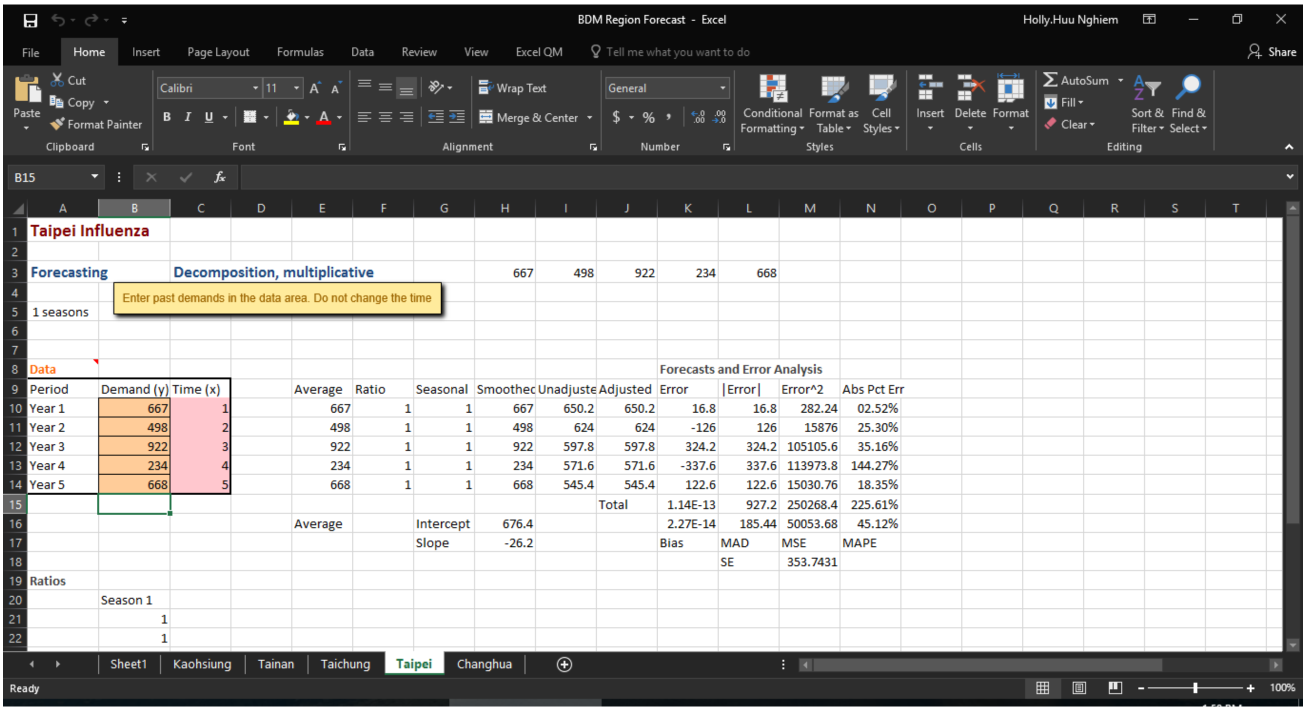
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Tainan Influenza													
2							171	75	114	100	265			
3	Forecasting		Decomposition, multiplicative											
4														
5	1 seasons													
6														
7														
8	Data										Forecasts and Error Analysis			
9	Period	Demand (y)	Time (x)		Average	Ratio	Seasonal	Smoothec	Unadjuste	Adjusted	Error	|Error|	Error^2	Abs Pct Err
10	Year 1	171	1		171	1	1	171	102.4	102.4	68.6	68.6	4705.96	40.12%
11	Year 2	75	2		75	1	1	75	123.7	123.7	-48.7	48.7	2371.69	64.93%
12	Year 3	114	3		114	1	1	114	145	145	-31	31	961	27.19%
13	Year 4	100	4		100	1	1	100	166.3	166.3	-66.3	66.3	4395.69	66.30%
14	Year 5	265	5		265	1	1	265	187.6	187.6	77.4	77.4	5990.76	29.21%
15		725								Total	0	292	18425.1	227.75%
16					Average		Intercept	81.1			0	58.4	3685.02	45.55%
17							Slope	21.3			Bias	MAD	MSE	MAPE
18												SE	95.98203	
19	Ratios													
20		Season 1												
21		1												
22		1												

Enter past demands in the data area. Do not change the time

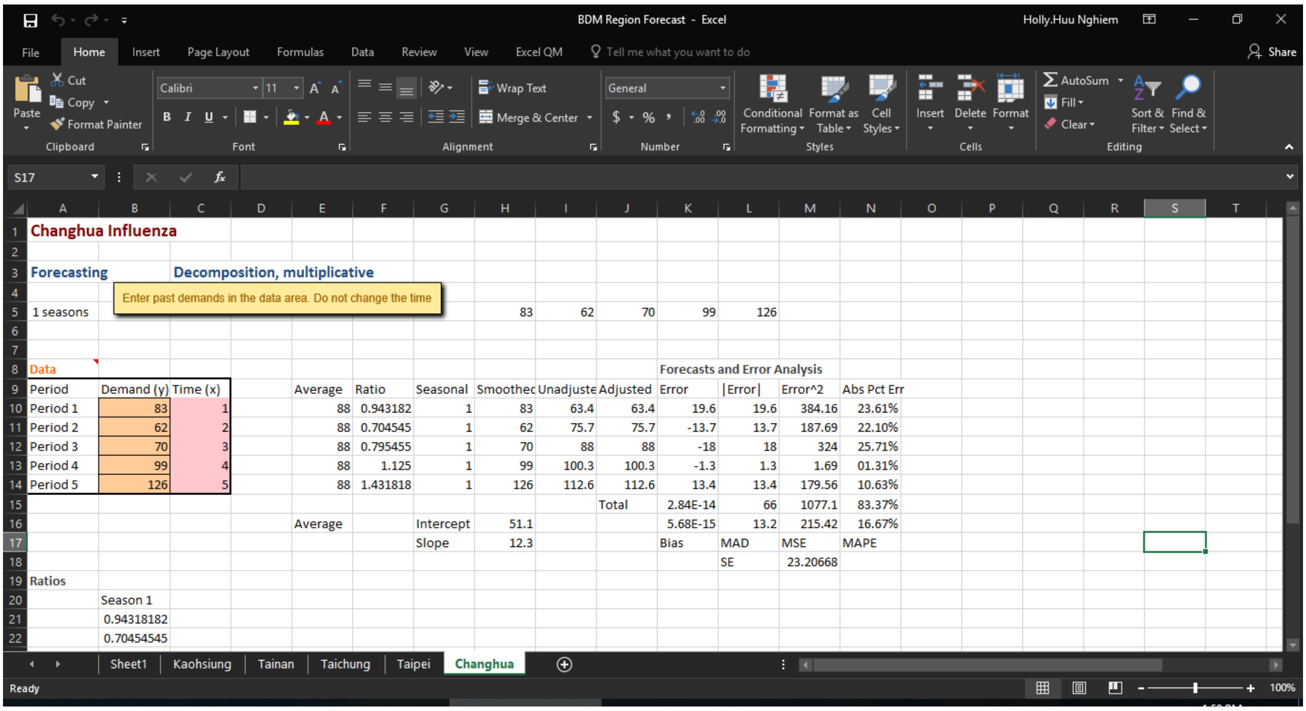
Sheet1 | Kaohsiung | Tainan | Taichung | Taipei | Changhua



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Taichung Influenza													
2														
3	Forecasting		Decomposition, multiplicative					67	29	59	53	190		
4			Enter past demands in the data area. Do not change the time											
5	1 seasons													
8	Data										Forecasts and Error Analysis			
9	Period	Demand (y)	Time (x)		Average	Ratio	Seasonal	Smoothec	Unadjuste	Adjusted	Error	|Error|	Error^2	Abs Pct Err
10	Year 1	67	1		67	1	1	67	25.6	25.6	41.4	41.4	1713.96	61.79%
11	Year 2	29	2		29	1	1	29	52.6	52.6	-23.6	23.6	556.96	81.38%
12	Year 3	59	3		59	1	1	59	79.6	79.6	-20.6	20.6	424.36	34.92%
13	Year 4	53	4		53	1	1	53	106.6	106.6	-53.6	53.6	2872.96	101.13%
14	Year 5	190	5		190	1	1	190	133.6	133.6	56.4	56.4	3180.96	29.68%
15		398								Total	0	195.6	8749.2	308.90%
16					Average		Intercept	-1.4			0	39.12	1749.84	61.78%
17							Slope	27			Bias	MAD	MSE	MAPE
18												SE	66.14076	
19	Ratios													
20		Season 1												
21		1												
22		1												



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Taipei Influenza													
2														
3	Forecasting		Decomposition, multiplicative					667	498	922	234	668		
4			Enter past demands in the data area. Do not change the time											
5	1 seasons													
8	Data										Forecasts and Error Analysis			
9	Period	Demand (y)	Time (x)		Average	Ratio	Seasonal	Smoothec	Unadjuste	Adjusted	Error	|Error|	Error^2	Abs Pct Err
10	Year 1	667	1		667	1	1	667	650.2	650.2	16.8	16.8	282.24	02.52%
11	Year 2	498	2		498	1	1	498	624	624	-126	126	15876	25.30%
12	Year 3	922	3		922	1	1	922	597.8	597.8	324.2	324.2	105105.6	35.16%
13	Year 4	234	4		234	1	1	234	571.6	571.6	-337.6	337.6	113973.8	144.27%
14	Year 5	668	5		668	1	1	668	545.4	545.4	122.6	122.6	15030.76	18.35%
15										Total	1.14E-13	927.2	250268.4	225.61%
16					Average		Intercept	676.4			2.27E-14	185.44	50053.68	45.12%
17							Slope	-26.2			Bias	MAD	MSE	MAPE
18												SE	353.7431	
19	Ratios													
20		Season 1												
21		1												
22		1												



Changhua Influenza

Forecasting — Decomposition, multiplicative

Enter past demands in the data area. Do not change the time

1 seasons — 83, 62, 70, 99, 126

Data

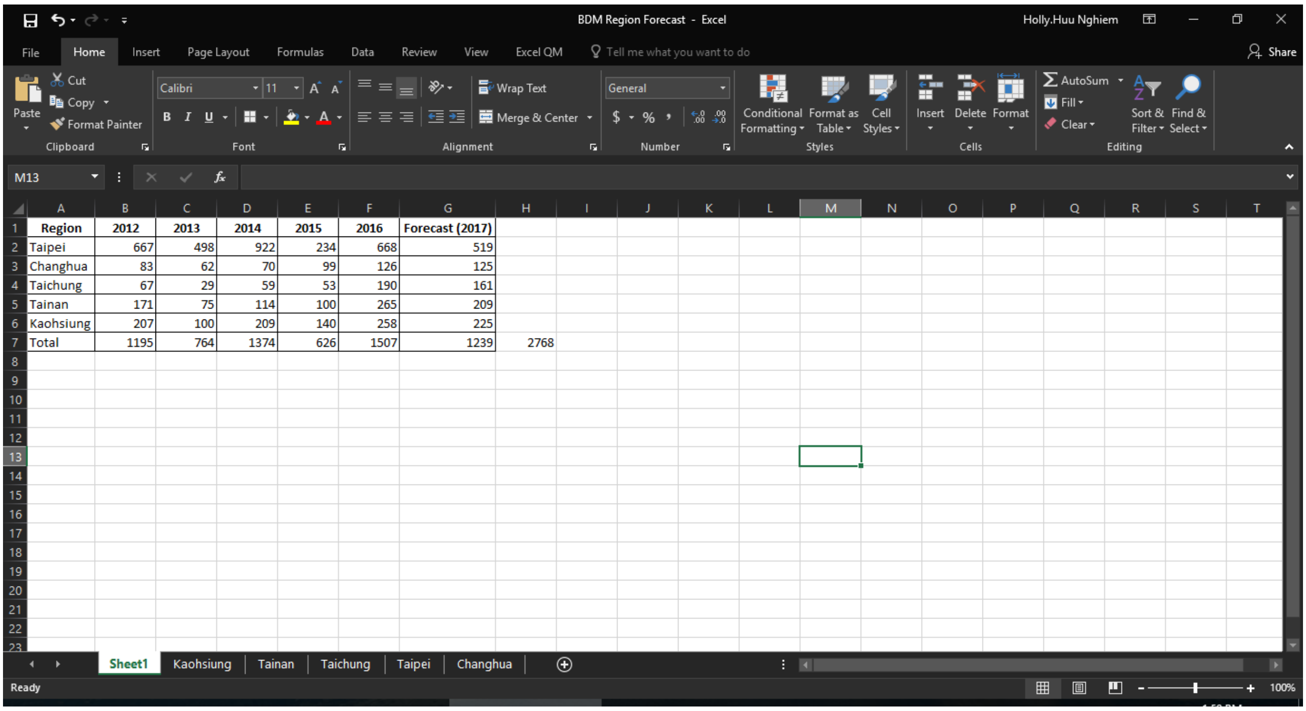
Period	Demand (y)	Time (x)		Average	Ratio	Seasonal	Smoothed	Unadjusted	Adjusted	Error	|Error|	Error^2	Abs Pct Err
Period 1	83	1		88	0.943182	1	83	63.4	63.4	19.6	19.6	384.16	23.61%
Period 2	62	2		88	0.704545	1	62	75.7	75.7	-13.7	13.7	187.69	22.10%
Period 3	70	3		88	0.795455	1	70	88	88	-18	18	324	25.71%
Period 4	99	4		88	1.125	1	99	100.3	100.3	-1.3	1.3	1.69	01.31%
Period 5	126	5		88	1.431818	1	126	112.6	112.6	13.4	13.4	179.56	10.63%
									Total	2.84E-14	66	1077.1	83.37%
				Average		Intercept	51.1			5.68E-15	13.2	215.42	16.67%
						Slope	12.3			Bias	MAD	MSE	MAPE
											SE	23.20668	

Ratios

Season 1

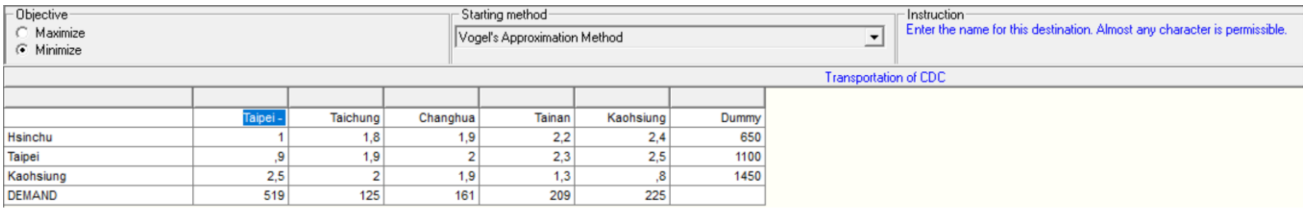
0.94318182

0.70454545



Region	2012	2013	2014	2015	2016	Forecast (2017)	
Taipei	667	498	922	234	668	519	
Changhua	83	62	70	99	126	125	
Taichung	67	29	59	53	190	161	
Tainan	171	75	114	100	265	209	
Kaohsiung	207	100	209	140	258	225	
Total	1195	764	1374	626	1507	1239	2768

5.2. Linear Programming Formulation



Objective: Maximize / Minimize (selected)

Starting method: Vogel's Approximation Method

Instruction: Enter the name for this destination. Almost any character is permissible.

Transportation of CDC

	Taipei -	Taichung	Changhua	Tainan	Kaohsiung	Dummy
Hsinchu	1	1,8	1,9	2,2	2,4	650
Taipei	,9	1,9	2	2,3	2,5	1100
Kaohsiung	2,5	2	1,9	1,3	,8	1450
DEMAND	519	125	161	209	225	

5.3. Linear Programming Result

Transportation Shipments

Optimal cost = $1449,7	Taipei - Taoyuan	Taichung	Changhua	Tainan	Kaohsiung	Dummy
Hsinchu		125	161			364
Taipei	519					581
Kaohsiung				209	225	1016

Iterations

	Taipei - Taoyuan	Taichung	Changhua	Tainan	Kaohsiung	Dummy
Iteration 1						
Hsinchu	(,1)	(-,1)	(-,1)	(-,1)	(1,6)	650
Taipei	519	125	161	209	(1,7)	86
Kaohsiung	(1,6)	(,1)	(-,1)	(-1)	225	1225
Iteration 2						
Hsinchu	(,1)	(-,1)	(-,1)	(,9)	(1,6)	650
Taipei	519	125	161	(1)	(1,7)	295
Kaohsiung	(1,6)	(,1)	(-,1)	209	225	1016
Iteration 3						
Hsinchu	(,1)	125	(-,1)	(,9)	(1,6)	525
Taipei	519	(,1)	161	(1)	(1,7)	420
Kaohsiung	(1,6)	(,2)	(-,1)	209	225	1016
Iteration 4						
Hsinchu	(,1)	125	161	(,9)	(1,6)	364
Taipei	519	(,1)	(,1)	(1)	(1,7)	581
Kaohsiung	(1,6)	(,2)	(0)	209	225	1016

Shipping list

From	To	Shipment	Cost per unit	Shipment cost
Hsinchu	Taichung	125	1,8	225
Hsinchu	Changhua	161	1,9	305,9
Hsinchu	Dummy	364	0	0
Taipei	Taipei -	519	,9	467,1
Taipei	Dummy	581	0	0
Kaohsiung	Tainan	209	1,3	271,7
Kaohsiung	Kaohsiung	225	,8	180
Kaohsiung	Dummy	1016	0	0

REFERENCE

http://www.cdc.gov.tw/english/info.aspx?treeid=BC2D4E89B154059B&nowtreeid=EE0A2987CFBA3222&tid=76493B3484122BE8

https://www.cdc.gov/flu/protect/preventing.htm

http://www.cdc.gov.tw/english/info.aspx?treeid=BC2D4E89B154059B&nowtreeid=EE0A2987CFBA3222&tid=95F4FE91B490297D

http://nidss.cdc.gov.tw/en/Default.aspx

http://www.cdc.gov.tw/english/list.aspx?treeid=00ED75D6C887BB27&nowtreeid=7EAD3CDB3DEAB590

http://www.cdc.gov.tw/english/list.aspx?treeid=00ED75D6C887BB27&nowtreeid=A49EE318FA9048CE

http://www.cdc.gov.tw/english/list.aspx?treeid=00ED75D6C887BB27&nowtreeid=CB0EE438660556E4

http://www.cdc.gov.tw/english/list.aspx?treeid=00ED75D6C887BB27&nowtreeid=9DA60C21712D45C4

http://www.cdc.gov.tw/english/infectionreport.aspx?treeid=3847719104BE0678&nowtreeid=73CE24F5D5C1FDA4

Render, B., Stair, R. M., Hanna, M. E. (2012) Quantitative analysis for management: Eleventh edition. New Jersey: Pearson Education Inc.