FORECASTING DEMAND OF INFLUENZA VACCINES AND TRANSPORTATION ANALYSIS.

GROUP MEMBER

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CONTENTS

1. Problem Formulation:

1.1. Purpose of research

1.2. Research objectives

1.3. Assumptions

1.1. PROBLEM FORMULATION:

1. Influenza is a major infectious disease in the winter in Taiwan. Every year, Center of Disease Center (C.D.C.) needs to **forecast the upcoming disease.** They also want to **forecast the trend, the seasonal trend,** of the influenza.
2. The influenza morbidity rate become higher. Influenza vaccination is the most effective way to prevent infection. However, the supply of influenza is limited. Accord to C.D.C, they are facing the transportation problem: **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.** Vaccine is fragile biologics. The vaccines need to be refrigerated, which makes transportation even more expensive.

1.2. RESEARCH OBJECTIVES

Forecast the number of influenza cases by using Time-series method.

Seeks to answer the transportation problem the C.D.C is facing by using linear programming .

1.3. Assumptions:

- Each source has a fixed supply of vaccines, entire supply must be distributed to the destinations.
- Each destination has a fixed demand for vaccines, entire demand must be received from the sources.
- The transportation cost is stable & provided by C.D.C.
- All answers or variables are nonnegative.
- Number in objective and constraints are known & do not change during the research.

2. Procedure/ Method:

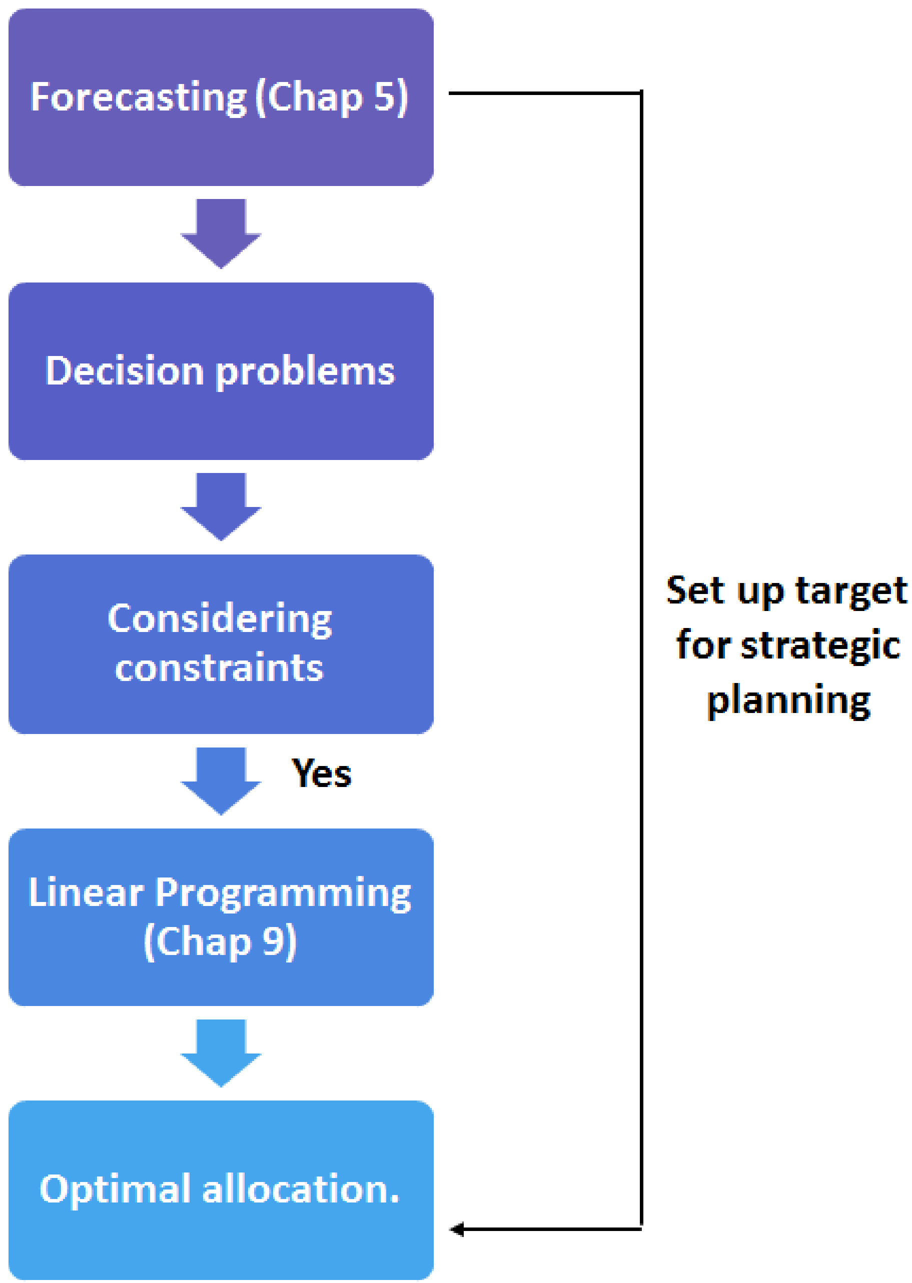
- This study will collect the past 5 year (2012 - 2016) data for the number of influenza cases happened in Taiwan. Source is from C.D.C. Taiwan.
- We will use Center Moving Average and Decomposition Method in Excel QM to analyze the trend and seasonal variances and forecast the number of influenza cases in 2017
- Using the forecasted demand we focus on the top 5 cities with highest number of cases and try to solve transportation problems to each cities
- Transportation cost per unit is collected from C.D.C. also and denominated in US Dollar per unit.

Systematic problem solving chart

Time series method

Transportation problem

- Transportation cost
- Limited supply.
- Demand in each regions



Limitations

- The data is obtained from C.D.C since January 2012 to December 2016.
- 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 become very complex.

Limitations

- The number of vaccines that are provided by the government (C.D.C.) to every regions. However, in this study we will only consider the constraints for demand in top 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

3.1.1. Trend Projections
3.1.2. Seasonal Variations with Trend
3.1.3. Using Regression with Trend and Seasonal Components
3.1.4. The Decomposition Method of Forecasting with Trend and Seasonal Components
3.1.5. Regional Demand Forecasting

3.2 Transportation problems

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

Source: Center for Disease Control.

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 in the past.

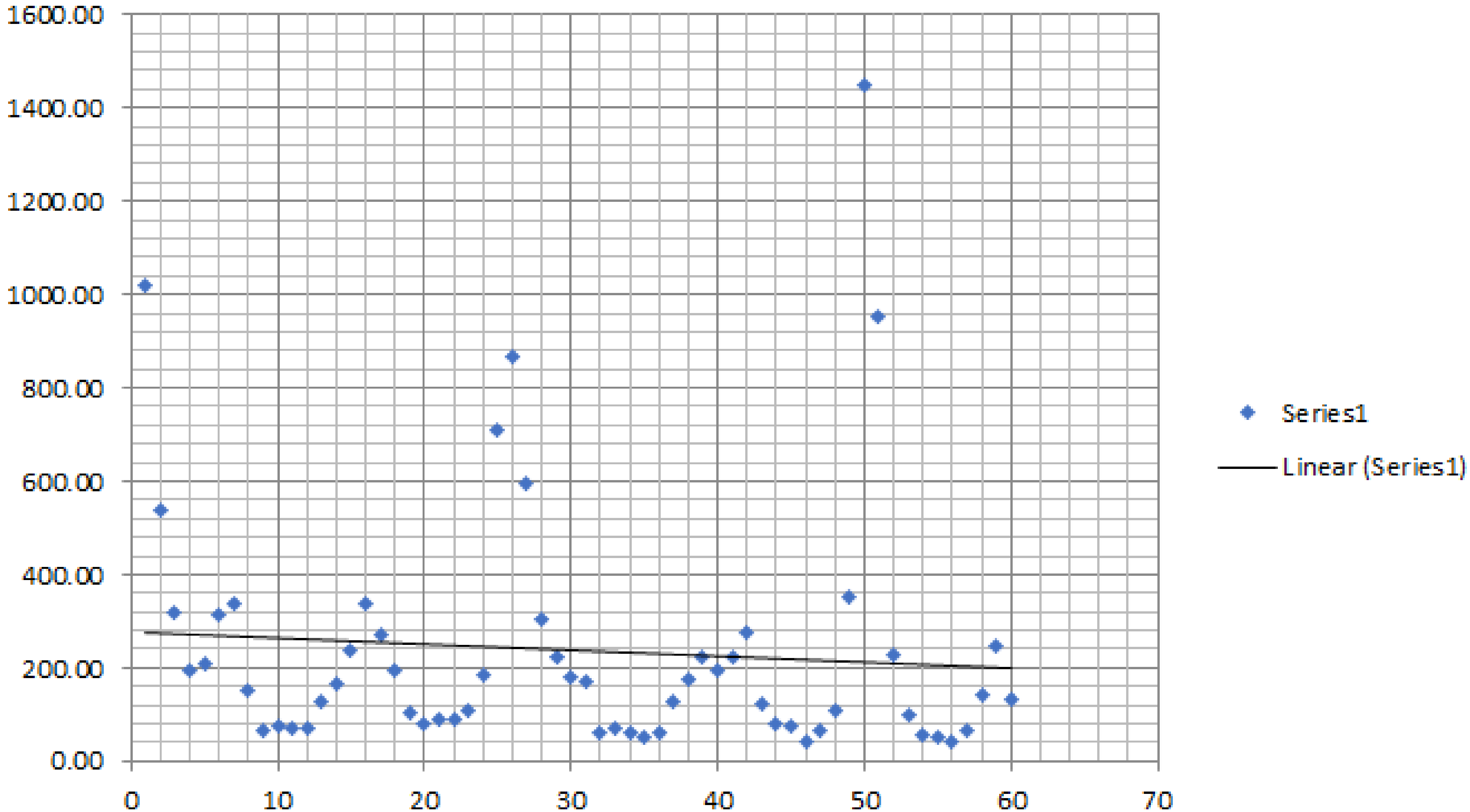
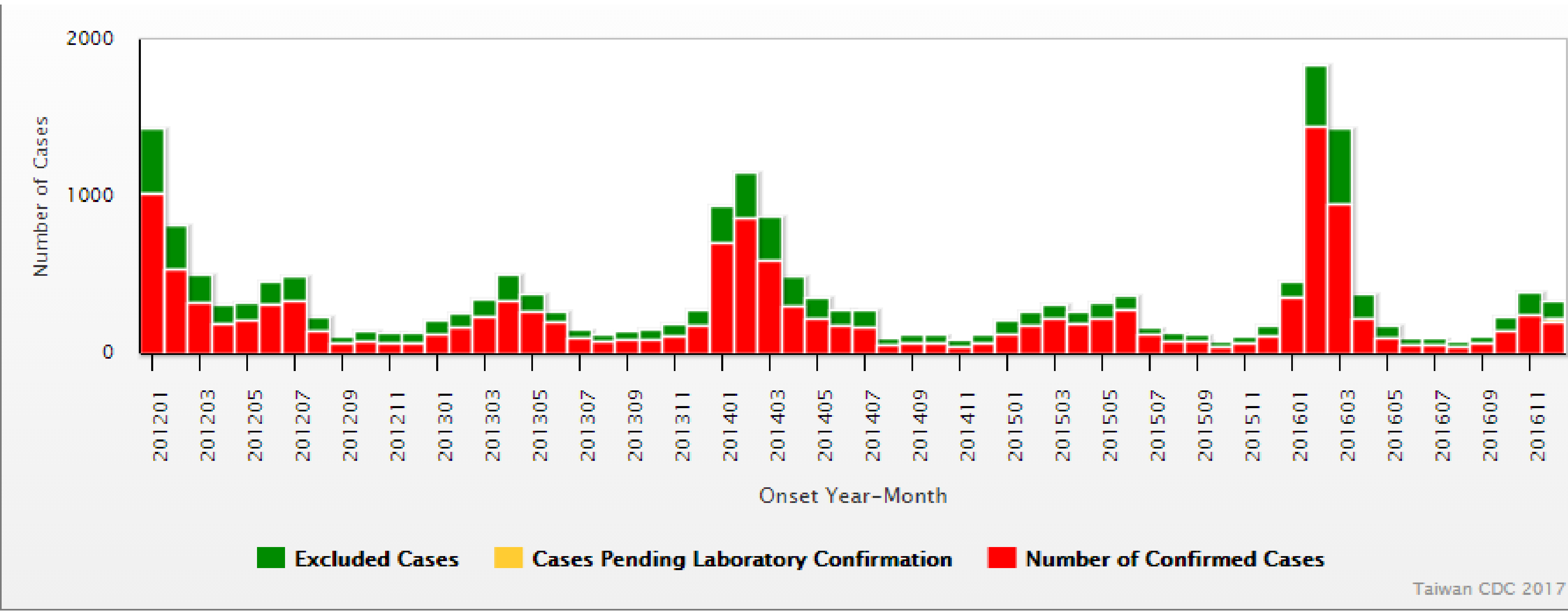


Figure: Taiwan Influenza and the Computed Trend Line.



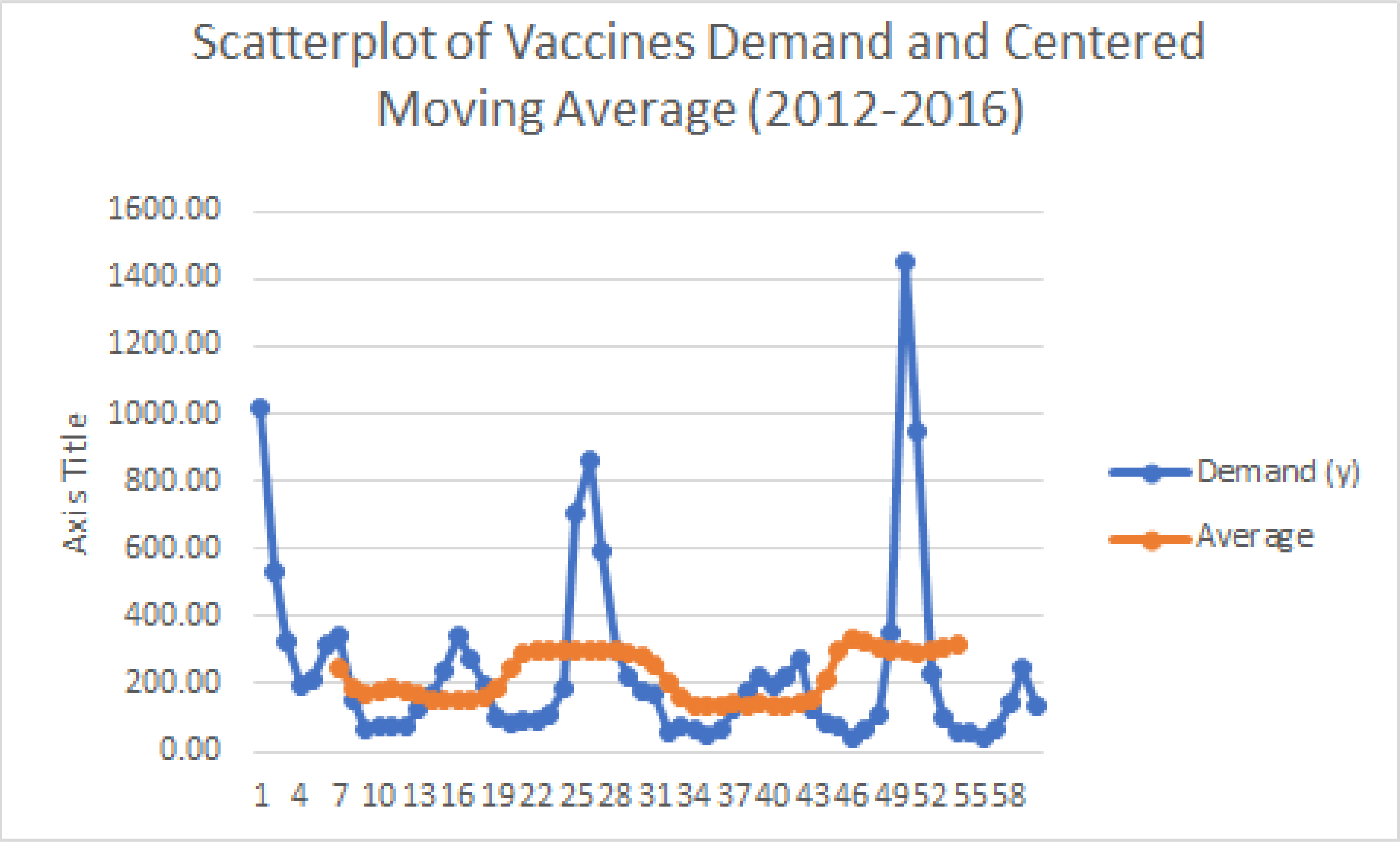
Source: Taiwan National Infectious Disease Statistics System

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.

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



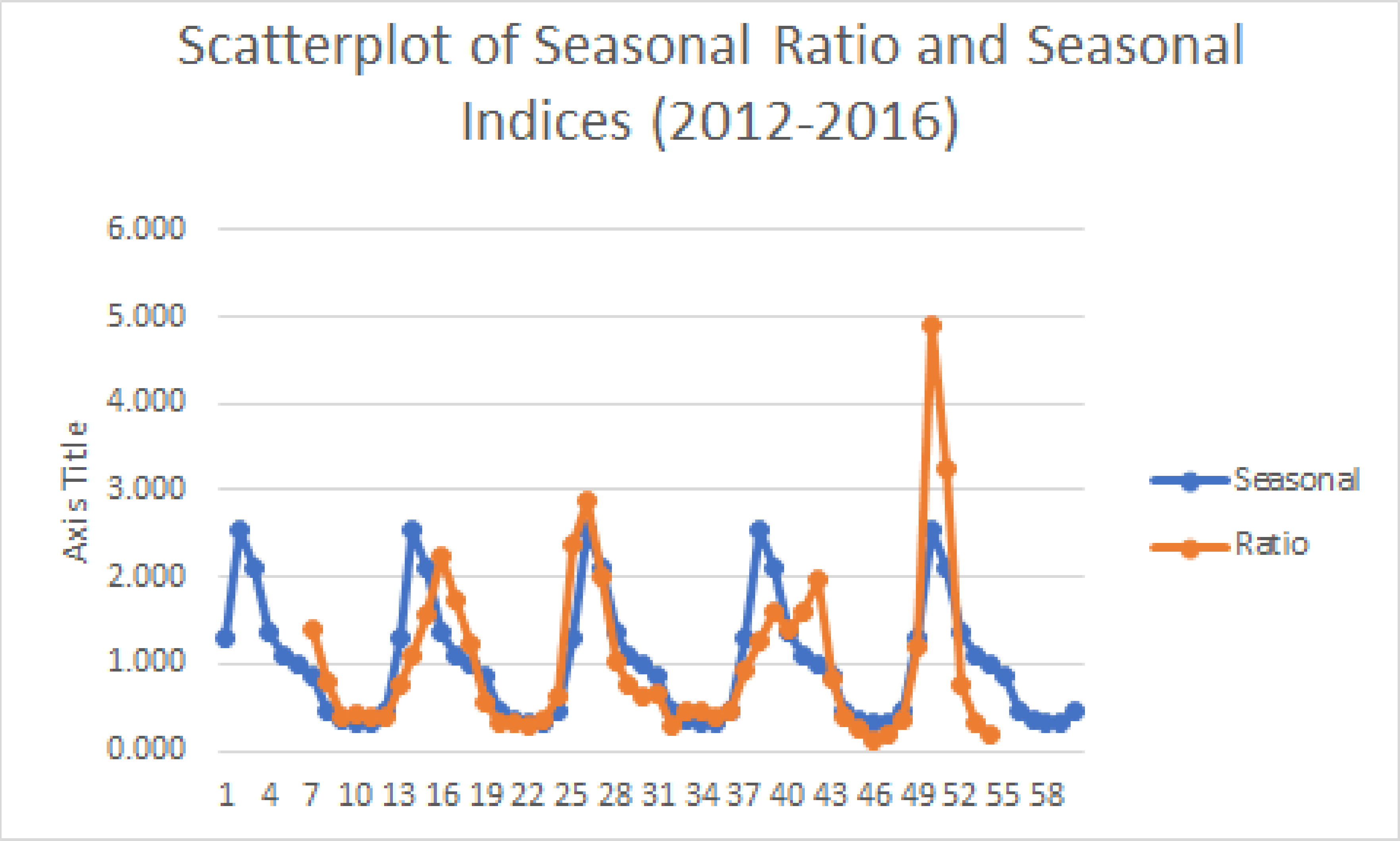
Scatterplot of Vaccines Demand and Centered Moving Average (2012-2016)
Axis Title
1600.00
1400.00
1200.00
1000.00
800.00
600.00
400.00
200.00
0.00
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58
Demand (y)
Average

	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: 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: Seasonal Indices based on CMA for Influenza Cases

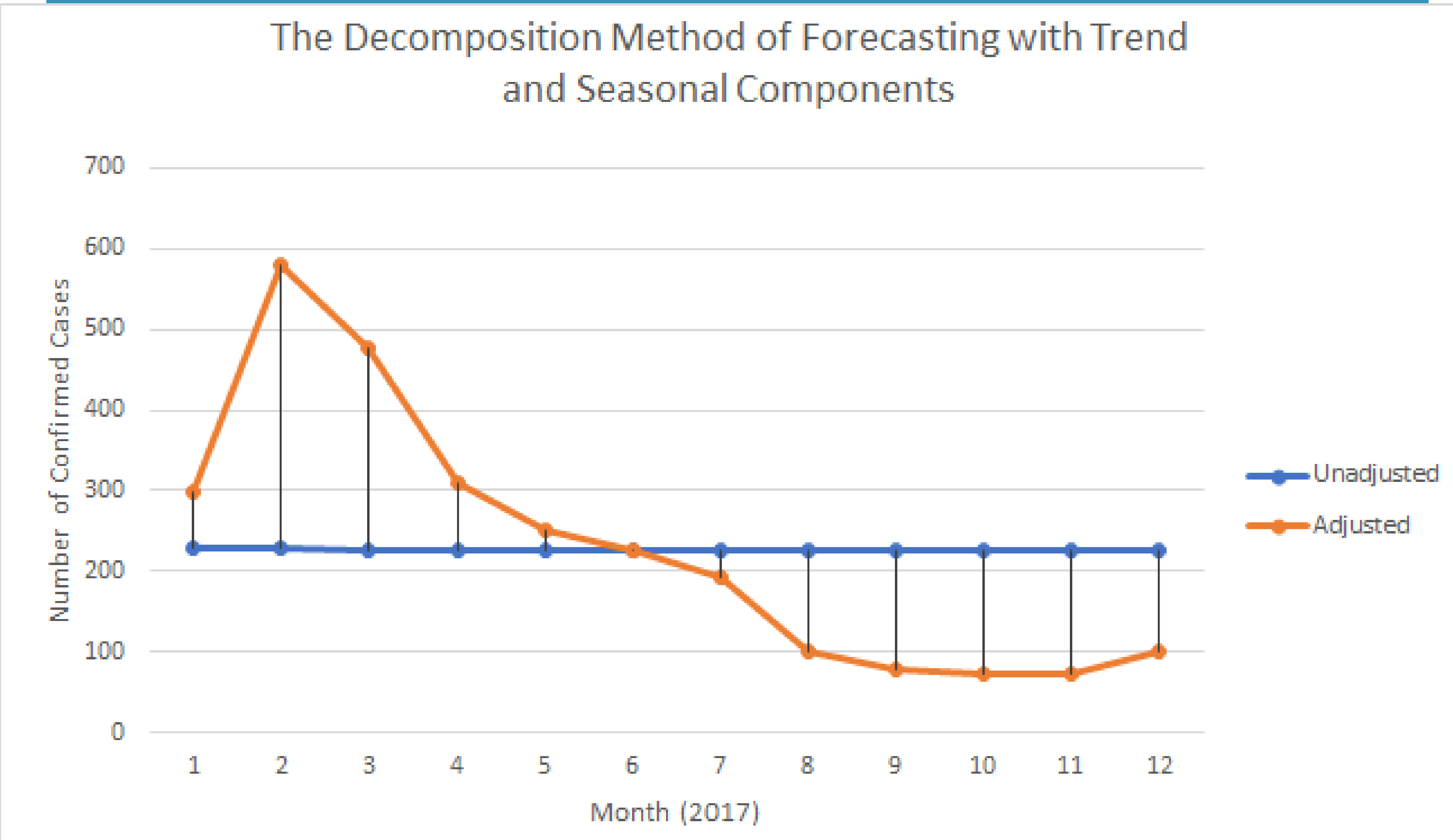

Scatterplot of Seasonal Ratio and Seasonal Indices (2012-2016)
6.000
5.000
4.000
3.000
2.000
1.000
0.000
Axis Title
1 4 7 10 13 16 19 22 25 28 31 34 37 40 43 46 49 52 55 58
Seasonal
Ratio

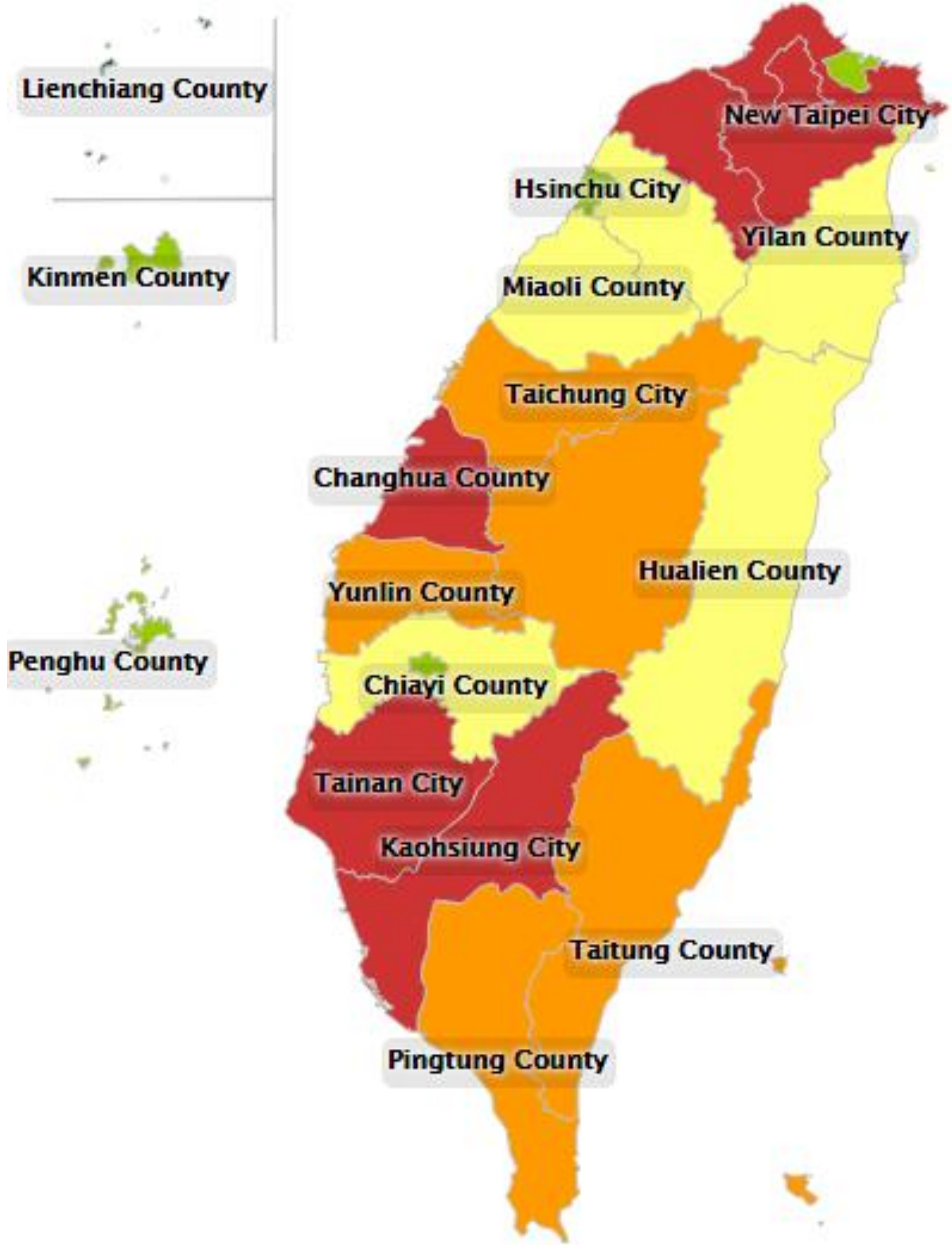
3.1.4. The Decomposition Method of Forecasting with Trend and Seasonal Components

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

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





3.1.5. Regional demand forecast:

Figure: Complicated influenza, indigenous, and imported, nationwide, 2012-2016

Source: Taiwan National Infectious Disease Statistics System

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
Kaosiung	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

Demand of Vaccines in 5 regions (Thousand Cases)

Source: Taiwan National Infectious Disease Statistics System

3.2 Transportation Problem:

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

Transportation cost per unit in US$
Source: MIS of Taiwan Centers for Disease Control

3.2 Transportation Problem:

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

Supply Capacity

Source: Taiwan Centers for Disease Control

Transportation Problem: LP Formulation

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

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

Transportation Problem: LP Formulation

Supply Constraints:

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

Demand Constraints:

- $X_{11} + X_{21} = 519$ (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)

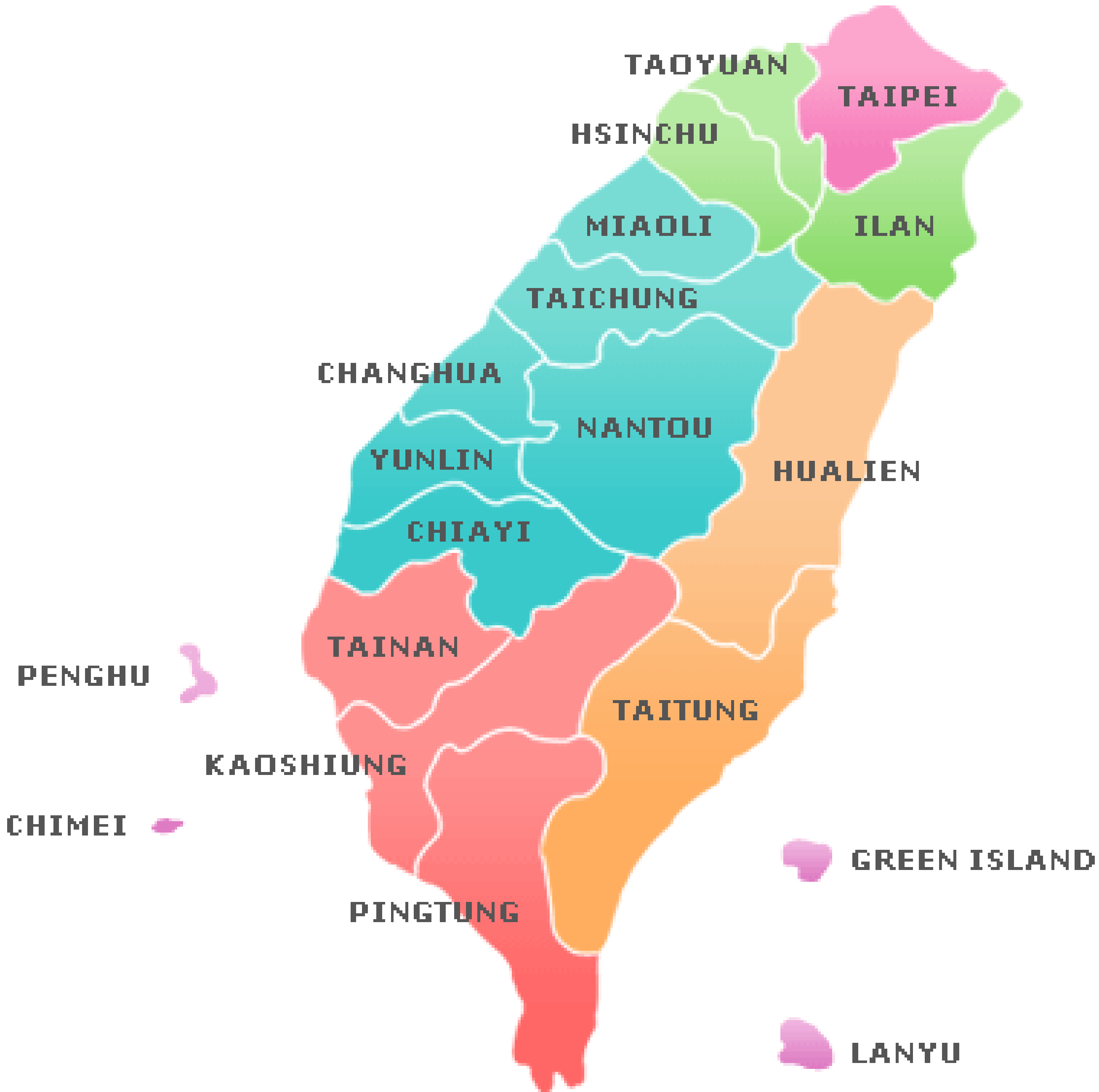
Transportation Problem: Optimal Result

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

Transportation Problem: Transportation Cost

From	To	Shipment	Cost / Unit	Cost
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

Transportation cost in thousands US$


TAOYUAN
TAIPEI
HSINCHU
MIAOLI
ILAN
TAICHUNG
CHANGHUA
NANTOU
YUNLIN
HUALIEN
CHIAYI
TAINAN
PENGHU
TAITUNG
KAOSHIUNG
CHIMEI
GREEN ISLAND
PINGTUNG
LANYU

4. Conclusion

4.1. Specific (applications)
4.2. General (principles)
4.3. Summary for management

4.1. Specific (applications):

- The cases will peak in February 2017 and will decrease gradually until December 2017. It is similar with the past trend.
- The highest number of cases are found in Taipei and Taoyuan, followed by Kaohsiung, Tainan, Changhua, and Taichung. → Taiwan C.D.C. can actively prepare for the flu season by distributing the vaccines through its warehouses to those cities.
- 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 to achieve minimal transportation cost.

4.2. General (principles):

- Vaccination should continue to be offered throughout the flu season, even in March or later. Since it takes about two weeks after vaccination for protecting against influenza virus infection, it is best that people get vaccinated in December.
- Flu vaccine is imported by the government, the timing of availability depends on when the import is completed. Shipments should be made in December.
- A flu vaccine is needed every season for two reasons. First, the body's immune response from vaccination declines over time. Second, because flu viruses are constantly changing, the formulation of the flu vaccine is reviewed each year. For the best protection, everyone 6 months and older should get vaccinated annually.

4.3. Summary for management:

- To prevent seasonal flu, the (C.D.C.) should recommend routine annual influenza vaccination for all persons aged 6 months or older, preferably before the onset of influenza activity in the community in December.
- Taiwan government should encourage the corporations urged to get employees vaccinated. Private companies and schools are encouraged to promote mass influenza vaccination.
- The C.D.C. should also addresses 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 this regions have the highest infectious rates.

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THANK YOU!