Chapter 4

Results and Discussion

4.1 Descriptive Statistic Analysis

The original data set of air pollution concentration from PCD is recorded in hourly basis, in order to perform the time series analysis in this study, it is transformed into mean daily data. Therefore, there are 5,234 daily observations starting from January 1996 – April 2010. From descriptive statistic in the table below, the concentration level of PM_{10} has the highest standard deviation and variance compare with other four air pollutants. Although SO_2 has the highest coefficient of variation that is 0.91, while it is 0.69 for PM_{10}, but the SO_2 concentration level is below the Ambient Air Standard. Thus, it does not matter for the high coefficient of the variation of SO_2. In addition, the minimum concentration level of PM_{10} is 8 µg/m^3 while the others are zero.

Table 4.1: Statistical data of air pollution data set

	Air Pollution Data – Daily Concentrations				
	(1) PM_{10}	**(2) O_3**	**(3) SO_2**	**(4) NO_2**	**(5) CO**
Mean	61.6347	14.9216	1.9997	13.1855	0.8628
Median	47.1786	13.1304	1.5909	11.391	0.7826
Maximum	396.4000	59.0000	25.6696	57.7500	5.5667
Minimum	8.0000	0.0000	0.0000	0.0000	0.0000
Std. Dev.	42.5648	8.0536	1.8284	8.2172	0.4914
Variance	1811.95	64.86	3.34	67.53	0.24
Coef. of variation	0.69	0.54	0.91	0.62	0.57
Ambient Air Standard	120 (µg/m^3)	100 (ppb)	300 (ppb)	170 (ppb)	30 (ppm)
Observations	5234	5234	5234	5234	5234

Source: Calculation

The National Ambient Air Standard of Thailand is inserted in the above table of statistical data, only the maximum level of PM_{10} concentration exceeds the National Ambient Air Standard. Please refer to the Ambient Air Standard table from PCD as below table 4.2 for more details. According to the air pollution data set in mean daily data, we select the average concentration in 24-hour for PM_{10}, 1-hour for O_3, SO_2, NO_2 and CO of Ambient Air Standard.

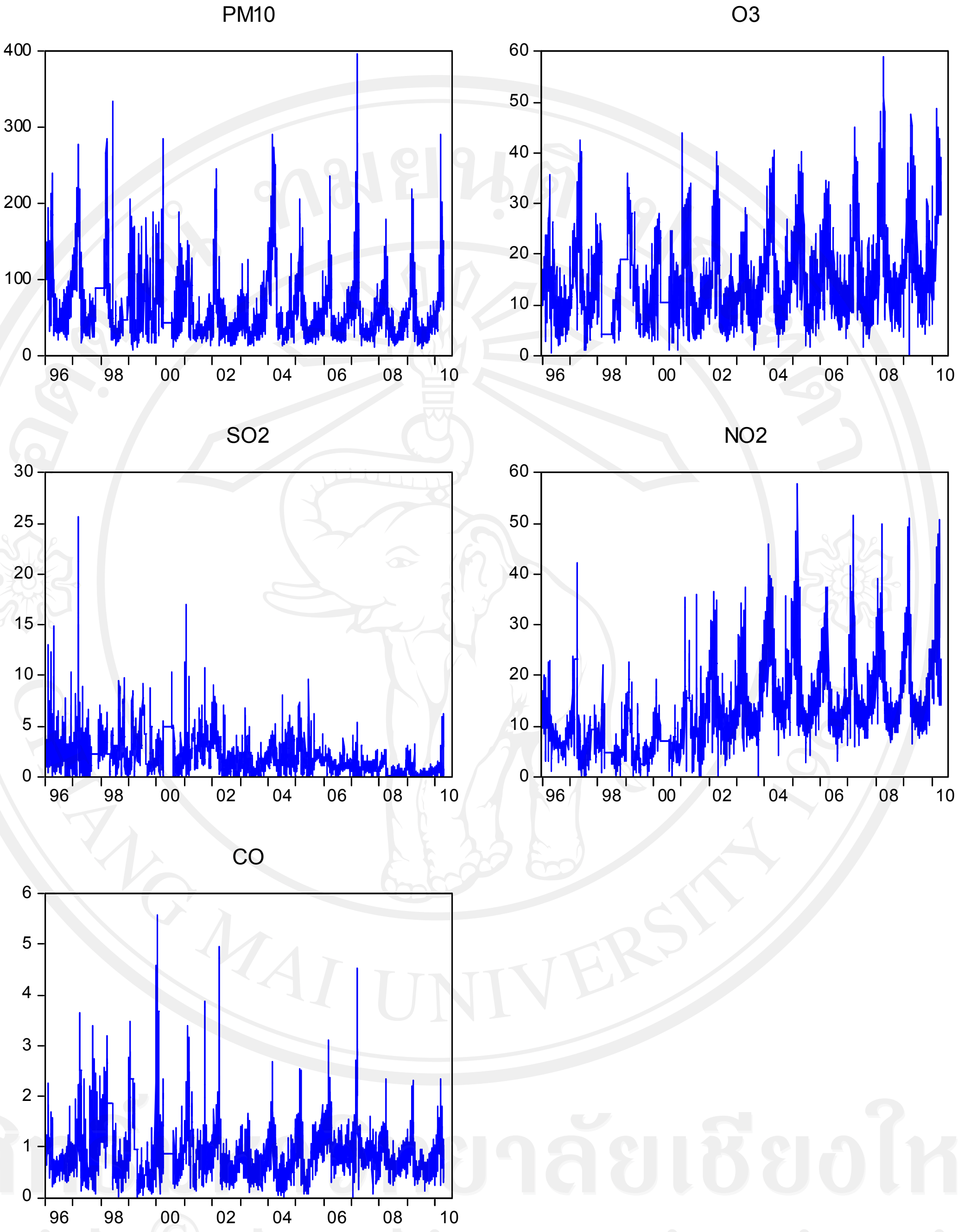
Table 4.2: National Ambient Air Standard for data set in the study

Air Pollutants	**Ambient Air Standard**	
	Average	**Standard**
1. PM_{10}	24 hour	Not exceed 120 µg/m^3
2. O_3 (Ground-level)	1 hour	Not exceed 100 ppb. (200 µg/m^3)
3. SO_2	1 hour	Not exceed 300 ppb.(780 µg/m^3)
4. NO_2	1 hour	Not exceed 170 ppb. (320 µg/m^3)
5. CO	1 hour	Not exceed 30 ppm. (34.2 mg/m^3)

Source: Pollution Control Department (PCD)

4.2 Time Series Plots

In order to get a preliminary understanding of time behavior of these air pollution's series, time series are plotted as the first step in time series analysis. The figure 4.1 below shows time series plots of air pollution daily concentrations. We can obviously see the seasonality in PM_{10}, O_3, NO_2, and CO movement.



Source: Calculation

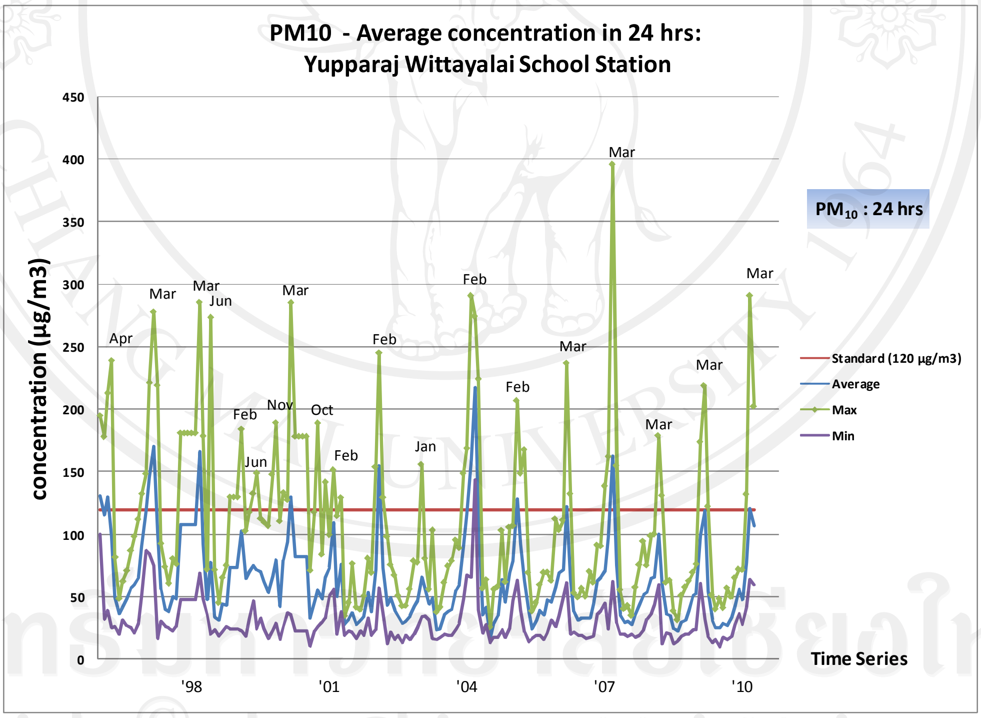
Figure 4.1: Time series plots of daily air pollution concentration

Monthly plot symbols are graphed for each air pollutants in the peak concentration levels in figure 4.2 (a) – (e) as well as the average and minimum concentration levels. Figure 4.2 (f) shows the comparison of PM_{10}, O_3, and NO_2 pattern which seem move similarly. We may define these five air pollutants into three groups according to the ambient air standard line in the figures; firstly, the peak concentrations of PM_{10} obviously exceed the standard. Secondly, the concentrations of O_3, SO_2 and CO are under the standard. Thirdly, the concentration of NO_2 is also under the standard but its peak level is closer the standard than O_3, SO_2 and CO (from second group as above).

From figure 4.2 (a), the highest PM_{10} concentration is in March 2007. Thaveesak (2007), from Bank of Thailand, reported the smoke situation in upper northern areas of Thailand where usually experience with the severe smoke problem, especially in March 2007 when the emission of PM_{10} was higher than the previous years crucially and higher than the ambient standard. He highlighted the two major causes of smoke problem in 2007 which are severe and more (i) forest fires from man-made and (ii) global warming which results a higher global average temperature and a distortion of natural system causes the environment change, meteorological condition change (e.g. El Nino phenomenon). This effect to the drier condition at the beginning of year 2007, brushes from dried leaves and plants are good fuels cumulated for forest fires to be happened easily. Besides, the ending of winter season in 2007 is delayed causes the air pressure intercepts the particles and smoke to spread out. Moreover, the burning from agriculture, factories, and transportation are still the basic cause of smoke problem.

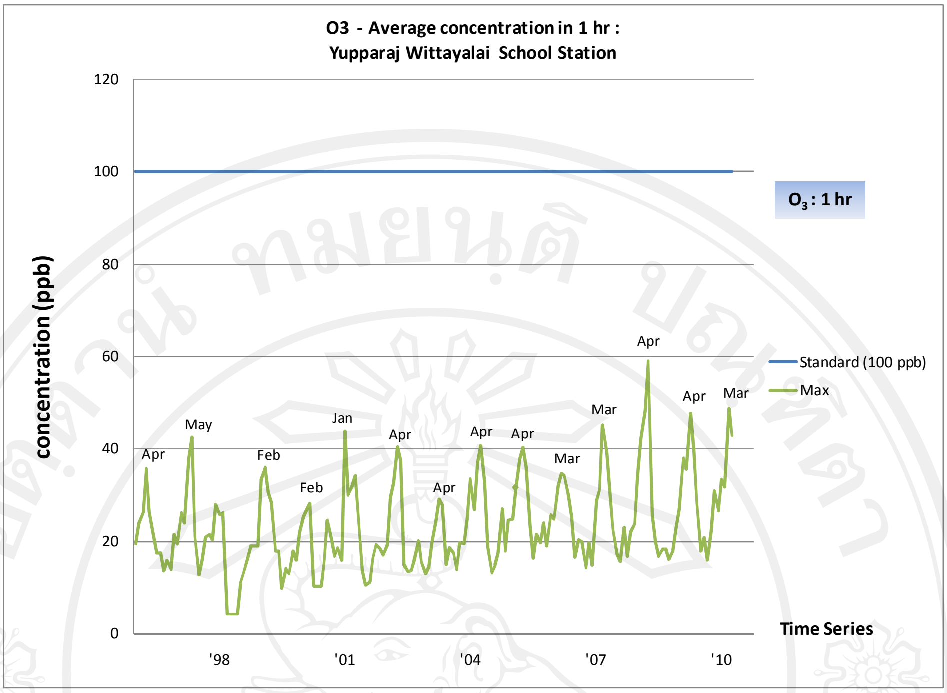
On the other hand, if we focus on an air pollution control, PM_{10} is the most critical air pollutants to be taken care of by the stakeholders (both policy maker and local people) since the maximum concentration is frequently over the national standard. NO_2 maximum concentration is not far below the national standard. O_3, SO_2, and CO maximum level is pretty far below the national standard but this should not be implied that we can ignore any policies or controls to be focused on in the future. In this case, if there would be any air pollution concentrations lower than the national standard, we may assume the current policies or air pollution control may be in active efficiently. Thus, stop using any measures may cause the air pollutions to be increased in the future gradually or immediately.

PM_{10}, O_3 and NO_2 seems to have a similar behavior that tend to be highest in the first quarter of the year (Jan – Mar; or +/- one month earlier/delay; this period could represent the lower temperature, hence, in the winter season). This may due mainly to the meteorological condition which occur more frequency during winter months; specifically, light winds, late night and early morning radiation inversions, which inhibit the vertical dispersion of air pollutants (South Coast Air Quality Management District, 2006)



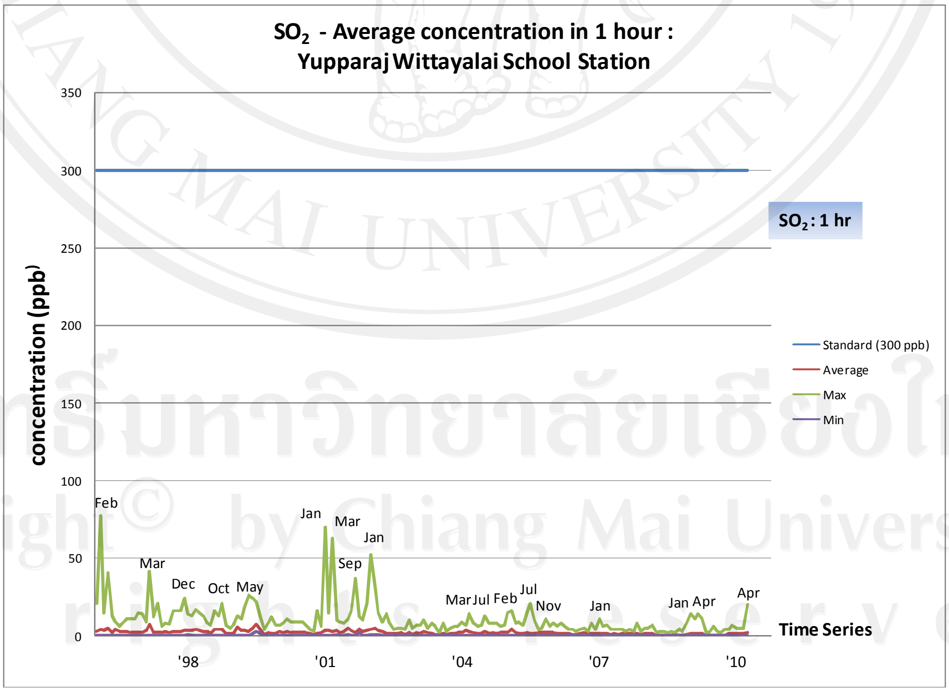
Source: Calculation

Figure 4.2 (a): Time series plots of monthly concentration – PM_{10}



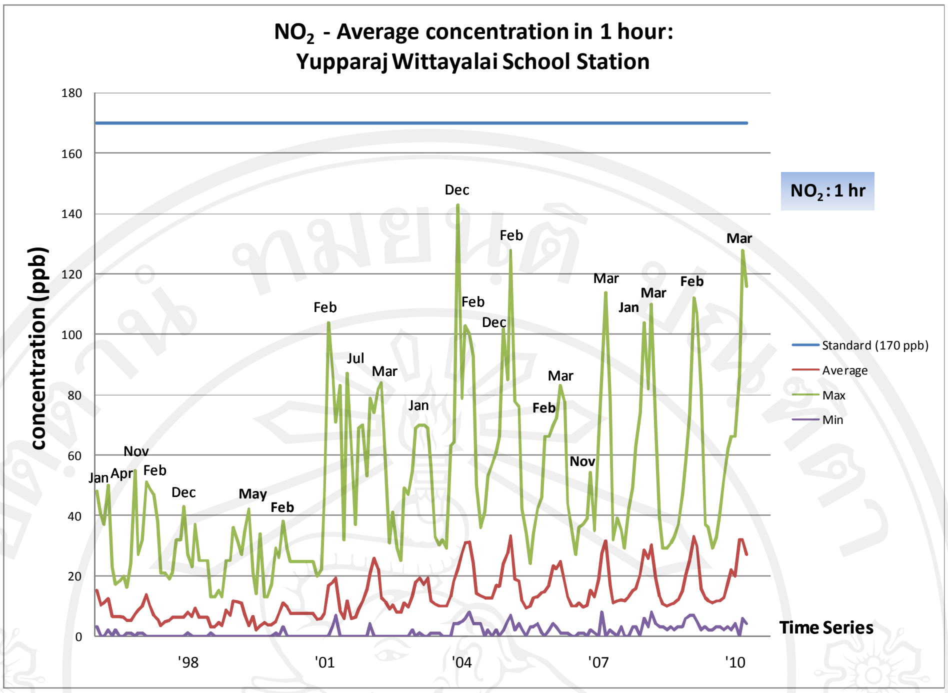
Source: Calculation

Figure 4.2 (b): Time series plots of monthly concentration – O_3



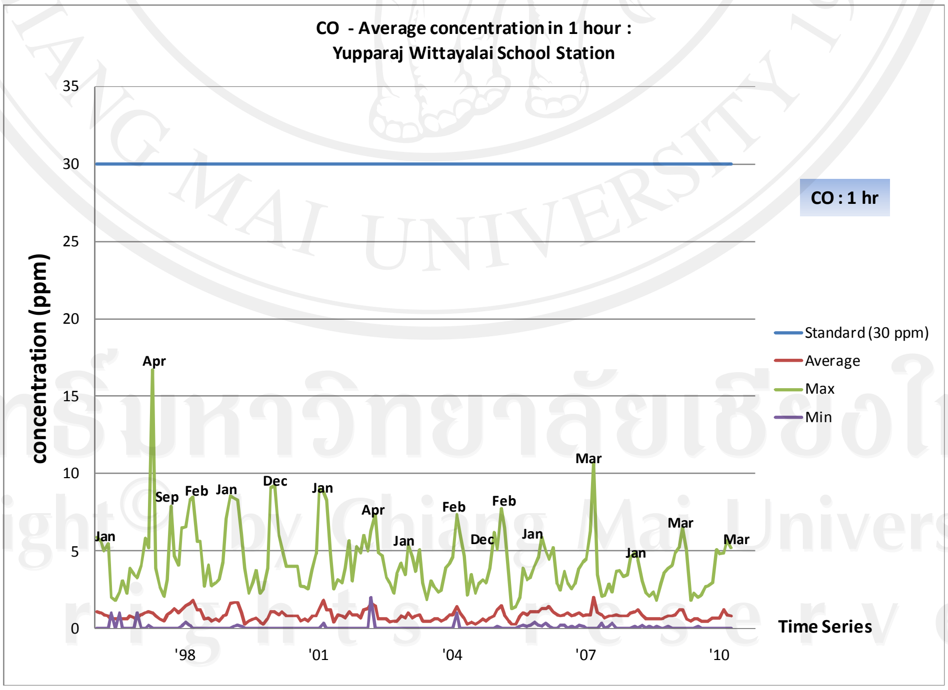
Source: Calculation

Figure 4.2 (c): Time series plots of monthly concentration – SO_2



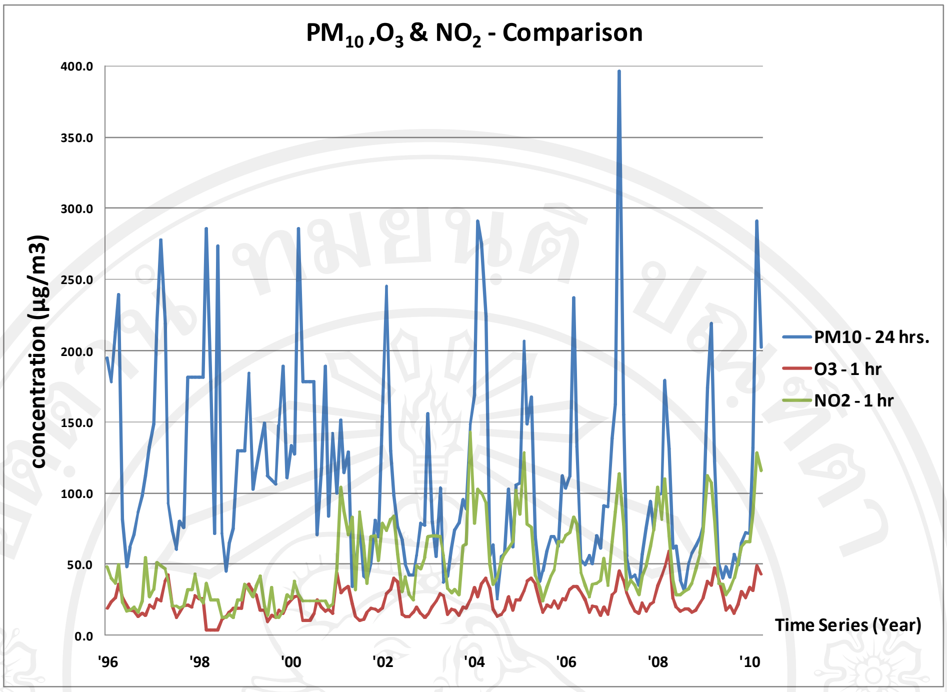
Source: Calculation

Figure 4.2 (d): Time series plots of monthly concentration – NO$_2$



Source: Calculation

Figure 4.2 (e): Time series plots of monthly concentration – CO



Source: Calculation

Figure 4.2 (f): Comparison of monthly concentration – PM_{10}, O_3, and NO_2

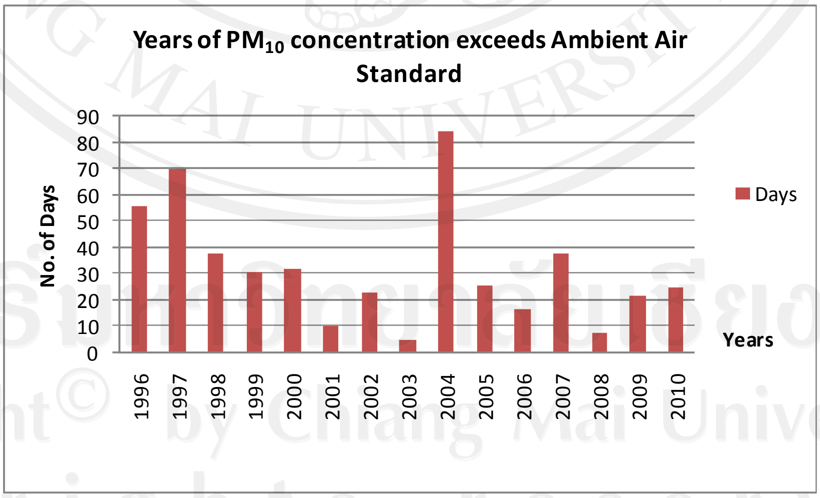
In order to analyze deeper in PM_{10} concentration, which is now treated as the most significant air pollutant among five primary air pollutions in the study, we will look into the period when the concentration levels move higher than the standard that may cause the health impacts to the people according to the color sign by AQI. From table 4.3 below reports the number of days with PM_{10} concentrations exceed ambient air standard for each year starting from 1996 – 2010. There are 84 days in 2004, 70 days in 1997, 56 days in 1996, 38 days in 1998 and 2007; these are top five of highest number of days, this situation can be seen from histogram in figure 4.3 below as well. From the original excel worksheet of data set, we can see that the situations of high PM_{10} concentration are mostly in January – April each year as well.

Table 4.3: Summary in years: Periods of PM_{10} exceeds Ambient Air Standard

Year	No. of days	Percentage	Months
1996	56	11.55%	Jan – Apr, Dec
1997	70	14.43%	Jan - Apr
1998	38	7.84%	Feb – Apr, Dec
1999	31	6.39%	Jan – Mar, May - Nov
2000	32	6.60%	Jan – Mar, Oct - Dec
2001	10	2.06%	Jan, Feb, Apr
2002	23	4.74%	Jan – Apr,
2003	5	1.03%	Jan, Apr, Dec
2004	84	17.32%	Jan – Apr, Oct
2005	26	5.36%	Feb – Apr, Aug - Sep
2006	17	3.51%	Mar - Apr
2007	38	7.84%	Feb - Apr
2008	8	1.65%	Mar - Apr
2009	22	4.54%	Feb - Apr
2010*	25	5.15%	Feb - Apr
SUM	**485 days**	**100%**	

Source: Calculation

Note: * Data is available for 4 months (Jan. – Apr. 2010)



Source: Calculation

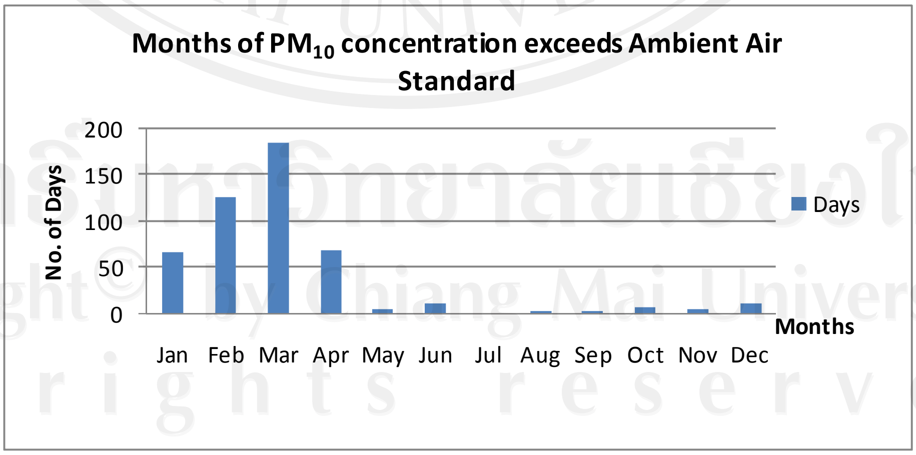
Figure 4.3: Years of PM_{10} concentration exceeds Ambient Air Standard

To analyze the months in the year when PM_{10} concentrations peak and exceed the standard, there is the summary in Table 4.4 of months in a year with the number of peak days. From the data set, there are 185 days in March, 126 days in February, 68 days in April, 65 days in January, this summary supports the above table that reports the most concerned period of peak PM_{10} concentration level which is in January – April each year. This four-month period is 91.54% of a whole year period. Figure 4.4 and 4.5 help to emphasize this crucial period.

Table 4.4: Summary in month: PM_{10} exceeds Ambient Air Standard

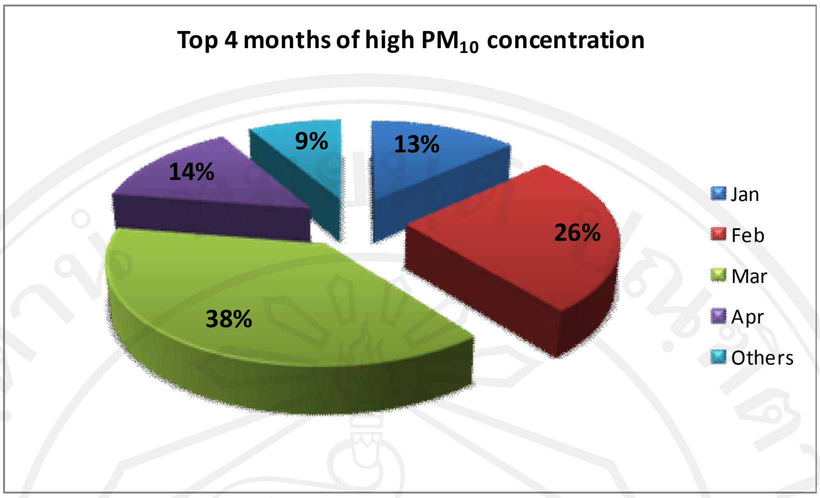
Months (from 1996-2010)	**Concentrations exceed national standard**	
	Days	**%**
Jan	65	13.40%
Feb	126	25.98%
Mar	185	38.14%
Apr	68	14.02%
May	4	0.82%
Jun	10	2.06%
Jul	-	-
Aug	2	0.41%
Sep	2	0.41%
Oct	7	1.44%
Nov	5	1.03%
Dec	11	2.27%
SUM	**485 days**	**100%**

Source: Calculation



Source: Calculation

Figure 4.4: Months and Days of PM_{10} concentration exceeds Ambient Air Standard



Source: Calculation

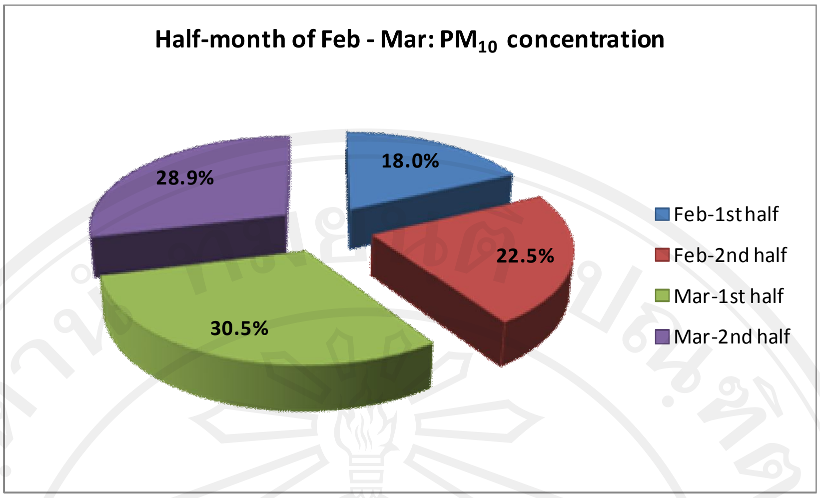
Figure 4.5: Top 4 months of high PM_{10} concentration

We now have the significant high PM_{10} concentration period that is from January – April each year. In order to investigate the specific peak times in a shorter certain time, we can look into 4 sub-periods (half a month or 15 days) in February and March which are the top two months of highest peak days. In the first-half month of February, there are 56 peak days and then up to 70 peak days in the second-half month, up again to 95 peak days in the first-half month of March and slight drop to 90 peak days in the second-half month. Therefore, we can conclude that the most critical period of PM_{10} concentrations is in March, it is 38.14% of peak days in this month for the last 14 years.

Table 4.5: Summary in Feb-Mar: PM_{10} exceeds Ambient Air Standard

Periods (1996 – 2010)	**Concentrations exceed national standard**	
	Days	**%**
Feb:		
- Beginning - mid	56	18%
- Mid - end	70	23%
Mar:		
- Beginning - mid	95	31%
- Mid - end	90	29%
SUM	**311 days**	**100%**

Source: Calculation



Source: Calculation

Figure 4.6: High PM_{10} concentration in Feb-Mar

4.3 Unit Root Test

Augmented Dickey-Fuller test is employed for stationary test, see the statistic summary in table 4.6 below. Since the calculated Dickey-Fuller test statistic of all five air pollutants are lower than the critical values (1%, 5%, and 10%) so that we reject the null hypothesis of non-stationarity. In other words, we conclude that five data sets of air pollution concentrations are stationary data at level in all 3 situations of include in test equation; which are constant (Intercept), a constant and linear trend (Trend and Intercept), and neither (None). Thus, the integrated order is zero or I(0). We have thus eliminated the “I” in the ARIMA formulation. Therefore there is no trend in the data over the past 14 years for any of the five air pollutants.

Table 4.6: Unit root test summary (ADF-test)

At level (Lag = 0)						
Air pollutants	**Intercept**		**Trend & Intercept**		**None**	
	ADF test Statistic	**% critical value**	**ADF test Statistic**	**% critical value**	**ADF test Statistic**	**% critical value**
(1) PM_{10}	-9.1045	1%: -3.4314 5%: -2.8619 10%: -2.5670	-9.2487	1%: -3.9598 5%: -3.4107 10%: -3.1271	-4.8231	1%: -2.5654 5%: -1.9409 10%: -1.6167
(2) O_3	-8.6843	1%: -3.4314 5%: -2.8619 10% -2.5670	-9.1651	1%: -3.9598 5%: -3.4107 10%: -3.1271	-3.0825	1%: -2.5654 5%: -1.9409 10%: -1.6167
(3) SO_2	-15.866	1%: -3.4314 5%: -2.8619 10% -2.5670	-18.403	1%: -3.9598 5%: -3.4107 10%: -3.1271	-6.0499	1%: -2.5654 5%: -1.9409 10%: -1.6167
(4) NO_2	-5.6880	1%: -3.4314 5%: -2.8619 10%: -2.5670	-7.9728	1%: -3.9598 5%: -3.4107 10%: -3.1271	-2.8518	1%: -2.5654 5%: -1.9409 10%: -1.6167
(5) CO	-9.0024	1%: -3.4314 5%: -2.8619 10%: -2.5670	-9.0607	1%: -3.9598 5%: -3.4107 10%: -3.1271	-3.7988	1%: -2.5654 5%: -1.9409 10%: -1.6167

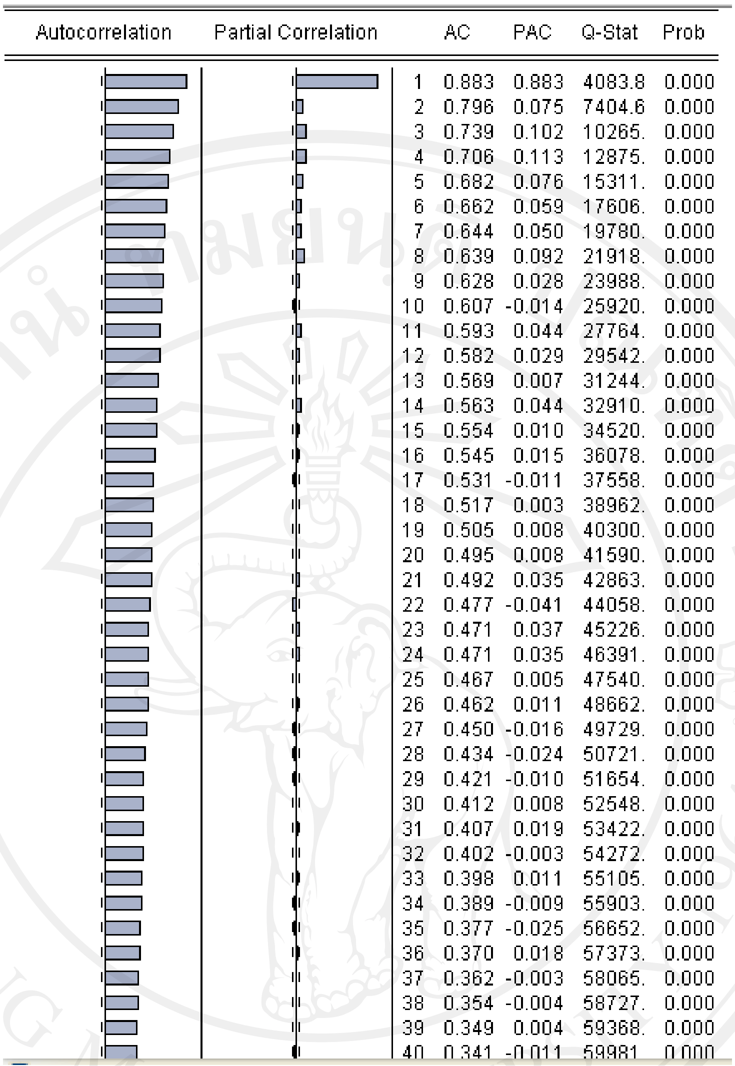
Source: Calculation

4.4 ARMA Modeling

Since PM_{10} is the most critical air pollutant due to its maximum concentrations which mostly exceed the national ambient air standard; and since the data give no evidence of a trend, the ARMA modeling, rather than the full ARIMA model, will be applied to this air pollutant specially.

4.4.1 Identification

From the correlogram in figure 4.7, we look at "Autocorrelation" (ACF) and "Partial Correlation" (PACF) to help indentify AR(p) and MA(q) for preferable models. We can observe the ACF exponential decays, and PACF spikes at lag one and much shorter at lag 2 – 5.



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Autocorrelation   Partial Correlation      AC     PAC    Q-Stat   Prob

                                       1  0.883  0.883  4083.8   0.000
                                       2  0.796  0.075  7404.6   0.000
                                       3  0.739  0.102  10265.   0.000
                                       4  0.706  0.113  12875.   0.000
                                       5  0.682  0.076  15311.   0.000
                                       6  0.662  0.059  17606.   0.000
                                       7  0.644  0.050  19780.   0.000
                                       8  0.639  0.092  21918.   0.000
                                       9  0.628  0.028  23988.   0.000
                                      10  0.607 -0.014  25920.   0.000
                                      11  0.593  0.044  27764.   0.000
                                      12  0.582  0.029  29542.   0.000
                                      13  0.569  0.007  31244.   0.000
                                      14  0.563  0.044  32910.   0.000
                                      15  0.554  0.010  34520.   0.000
                                      16  0.545  0.015  36078.   0.000
                                      17  0.531 -0.011  37558.   0.000
                                      18  0.517  0.003  38962.   0.000
                                      19  0.505  0.008  40300.   0.000
                                      20  0.495  0.008  41590.   0.000
                                      21  0.492  0.035  42863.   0.000
                                      22  0.477 -0.041  44058.   0.000
                                      23  0.471  0.037  45226.   0.000
                                      24  0.471  0.035  46391.   0.000
                                      25  0.467  0.005  47540.   0.000
                                      26  0.462  0.011  48662.   0.000
                                      27  0.450 -0.016  49729.   0.000
                                      28  0.434 -0.024  50721.   0.000
                                      29  0.421 -0.010  51654.   0.000
                                      30  0.412  0.008  52548.   0.000
                                      31  0.407  0.019  53422.   0.000
                                      32  0.402 -0.003  54272.   0.000
                                      33  0.398  0.011  55105.   0.000
                                      34  0.389 -0.009  55903.   0.000
                                      35  0.377 -0.025  56652.   0.000
                                      36  0.370  0.018  57373.   0.000
                                      37  0.362 -0.003  58065.   0.000
                                      38  0.354 -0.004  58727.   0.000
                                      39  0.349  0.004  59368.   0.000
                                      40  0.341 -0.011  59981.   0.000
```

Source: Calculation

Figure 4.7: PM_{10} Correlogram

Three preferred models are identified below.

Log(PM) = C + AR(1) + AR(2) + MA(1) + MA(2) + MA(3) + MA(4) + MA(5)

(Model 4.1)

Log(PM) = C + AR(1) + AR(2) + AR(3) + MA(1) + MA(2) + MA(3) + MA(4)

(Model 4.2)

Log(PM) = C + AR(1) + MA(1) + MA(2) + MA(3) + MA(4) + MA(5)

(Model 4.3)

where

PM = PM_{10} concentration

C = constant term

AR(p) = autoregressive lag length(p)

MA(q) = moving average lag length(q)

4.4.2 Estimation

Three models from identification phase are estimated, the output is shown below in table 4.7 including t-statistic values. All coefficients of AR(p) and MA(q) are significantly different from zero at the 5% critical value. In other words, the dependent variables are able to explain the independent variables at the significant level of 5%. The adjusted R-squared from three models are about 0.78, this means the dependent variable from three models are able to explain the independent variables at 78%. These adjusted R-squared statistics are high and close to each other with high value of F-statistic as well.

Table 4.7: Model Estimation

Model	Model (4.1)	Model (4.2)	Model (4.3)
	Coefficients		
C	3.922019 (47.54651)	3.922434 (47.83596)	3.924029 (49.55292)
AR(1)	1.519853 (6.682795)	0.499263 (7.187801)	0.983644 (321.4875)
AR(2)	-0.526663 (-2.354470)	0.954700 (28.12736)	-
AR(3)	-	-0.469004 (-6.997786)	-
MA(1)	-0.828951 (-3.638621)	0.192757 (2.737538)	-0.293298 (-20.68753)
MA(2)	-0.009256 (-0.134463)	-0.786468 (-14.78087)	-0.167784 (-11.51126)
MA(3)	-0.025555 (-0.609902)	-0.051463 (-1.218538)	-0.117924 (-8.060427)
MA(4)	0.011515 (0.363570)	-0.035780 (-1.438798)	-0.054117 (-3.721715)
MA(5)	-0.002499 (-0.100230)	-	-0.031842 (-2.262849)
R-squared	0.783031	0.783101	0.782915
Adjusted R-squared	0.782741	0.782811	0.782666
F-statistic	2693.316	2693.910	3141.250
Log Likelihood	-746.7896	-745.0902	-748.7790
Durbin-Watson Stat	1.999940	2.000393	1.998048

Source: Calculation

Note: t-statistic in ( )

The Durbin-Watson statistic measures the serial correlation in the residuals. DW statistics from all three models are around 2, this implies no serial correlation or there is zero autocorrelation of residuals; the DW statistic will fall below 2 if there is positive serial correlation (in the worst case, it will be near zero) and if there is negative correlation, the statistic will lie somewhere between 2 and 4.

From table 4.8, all three criterions of AIC, SC, and HQ are close to each other for three models at about 0.29. However, Model (4.2) has the minimum statistics of AIC and HQ while Model (4.3) has the minimum SC.

We now can conclude that all three models are reasonable to be used for the next step of ARMA.

Table 4.8: Model Selection Criterion

Criterion	Model (4.1)	Model (4.2)	Model (4.3)
Akaike info criterion	0.288528	0.287934*	0.288851
Schwarz criterion	0.298563	0.297970	0.297630*
Hannan-Quinn criterion	0.292037	0.291443*	0.291921

Source: Calculation

Note: * The minimum statistic

The equation for ARMA models are below.

$$PM_t=\mu+ \theta_1 PM_{t-1}+ \theta_2 PM_{t-2}+\ldots+ \theta_p PM_{t-p}+ e_t- \theta_1 e_{t-1}- \theta_2 e_{t-2}-\ldots- \theta_q e_{t-q}$$

where;

PM = Log of PM_{10} Concentration

μ = Constant term

θ = Autoregressive parameter

e = Error term

p = Autoregressive order (lags)

q = Moving average order (lags)

t = Period of time

From **model (4.1)** estimation**:** This estimation result corresponds to the following specification;

LOG(PM) = C(1) + [AR(1) = C(2), AR(2) = C(3), MA(1) = C(4), MA(2) = C(5),
MA(3) = C(6), MA(4) = C(7), MA(5) = C(8)]

or substituted coefficients;

LOG(PM) = 3.92 + [AR(1) = 1.52, AR(2) = -0.53, MA(1) = -0.83, MA(2) = -0.01,
MA(3) = -0.03, MA(4) = 0.01, MA(5) = -0.002]

From **model (4.2)** estimation**:** This estimation result corresponds to the following specification;

LOG(PM) = C(1) + [AR(1) = C(2), AR(2) = C(3), AR(3) = C(4), MA(1) = C(5),
MA(2) = C(6), MA(3) = C(7), MA(4) = C(8)]

or substituted coefficients;

LOG(PM) = 3.92 + [AR(1) = 0.50, AR(2) = 0.95, AR(3) = -0.47, MA(1) = 0.19,
MA(2) = -0.79, MA(3) = -0.05, MA(4) = -0.04]

From **model (4.3)** estimation**:** This estimation result corresponds to the following specification;

LOG(PM) = C(1) + [AR(1) = C(2), MA(1) = C(3), MA(2) = C(4), MA(3) = C(5),
MA(4) = C(6), MA(5) = C(7)]

or substituted coefficients;

LOG(PM) = 3.92 + [AR(1) = 0.98, MA(1) = -0.29, MA(2) = -0.17, MA(3) = -0.12,
MA(4) = -0.05,MA(5) = -0.03]

4.4.3 Diagnostic Checking

If ARMA model is correctly specified, the residuals from the model should be nearly white noise. This means that there should be no serial correlation left in the residuals. From table 4.9, all three models are diagnostic checked for white noise of estimated residuals *(e_t)* and found Q-statistics are not significantly different from zero at 5% level, thus e_t has the white noise property and no autocorrelation or heteroscedasticity. This implies all models are suitable for the next step of forecasting.

Table 4.9: Diagnostic checking of models

Stat.	**Models**		
	Model 4.1	**Model 4.2**	**Model 4.3**
Q-Statistic	42.895	41.220	46.035
Probability	0.047	0.066	0.031
Lag	36	36	36

Source: Calculation

4.4.4 Forecasting

The identified models are reviewed the statistical in order to select the minimum errors. In this stage, Root Mean Squared Error and Theil Inequality Coefficient are employed. There are three processes of forecasting.

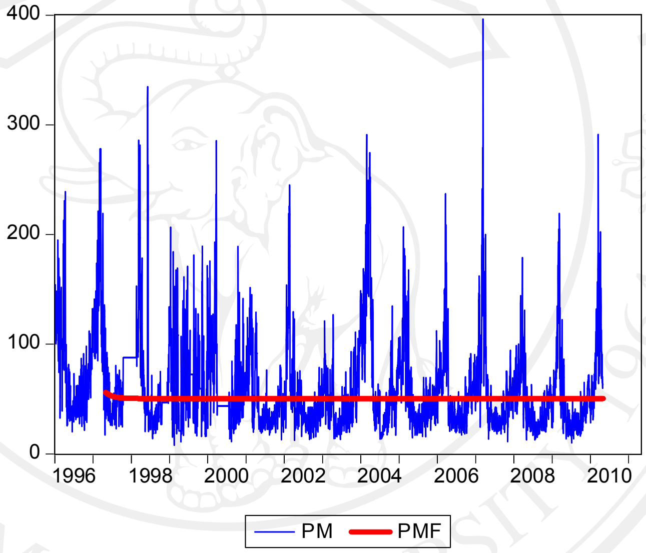
(i) ***Historical Forecast***: Long backcast 13 years of daily PM_{10} concentration from May 1st, 1997-April 30th, 2010 and check the minimum error statistics as below table 4.10. RMSE suggests Model (4.1) but Theil Inequality Coefficient suggests Model (4.2). The backcast graphs compared with the actual concentrations for both models are in figure 4.8 (a) and (b).

Table 4.10: Statistic for Historical Forecast

Statistic	**Model (4.1)**	**Model (4.2)**	**Model (4.3)**
Root Mean Squared Error (RMSE)	42.93825*	42.93966	42.95617
Theil Inequality Coefficient (U)	0.343212	0.343187*	0.343206

Source: Calculation

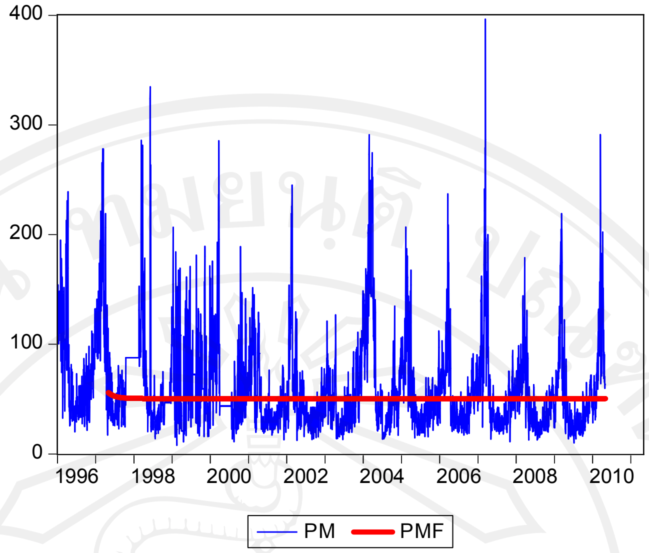
Note: * The minimum statistics



Source: Calculation

Note: PM = Actual PM_{10} concentration, PMF = PM_{10} Forecast concentration

Figure 4.8 (a): Historical Forecast of PM_{10} Concentration from Model (4.1) (May 1st, 1997-Apr 30th, 2010)



Source: Calculation

Note: PM = Actual PM_{10} concentration, PMF = PM_{10} Forecast concentration

Figure 4.8 (b): Historical Forecast of PM_{10} Concentration from model (4.2) (May 1st, 1997-Apr 30th, 2010)

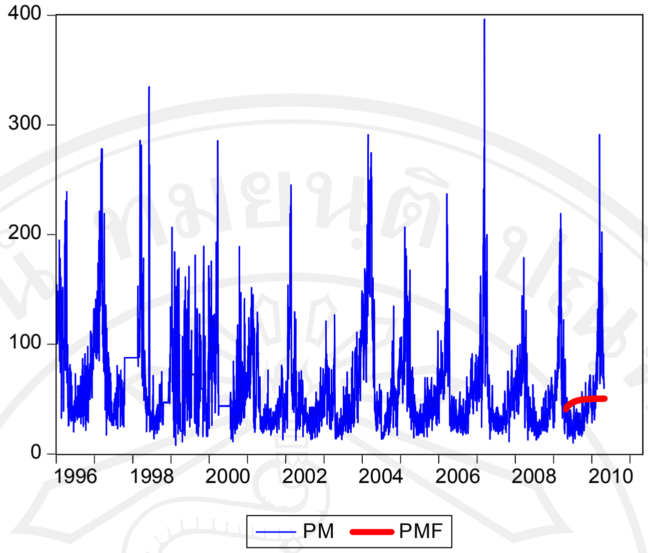
(ii) ***Ex-post Forecast***: Short backcast 1 year of daily PM_{10} concentration from May 1st, 2009-April 30th, 2010 and check the minimum error statistics as below table 4.11. RMSE suggests Model (4.1) but Theil Inequality Coefficient suggest Model (4.3). The backcast graphs compared with the actual concentrations for both models are in figure 4.9 (a) and (b).

Table 4.11: Statistic for Ex-post Forecast

Statistic	**Model (4.1)**	**Model (4.2)**	**Model (4.3)**
Root Mean Squared Error (RMSE)	36.77702*	36.77825	36.79388
Theil Inequality Coefficient (U)	0.326650	0.326562	0.326257*

Source: Calculation

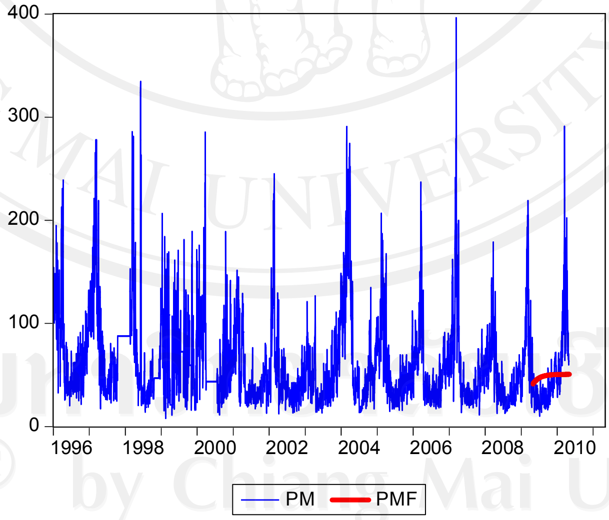
Note: * The minimum statistics



Source: Calculation

Note: PM = Actual PM_{10} concentration, PMF = PM_{10} Forecast concentration

Figure 4.9 (a): Ex-post Forecast of PM_{10} Concentration from Model (4.1) (May 1st, 2009-Apr 30th, 2010)

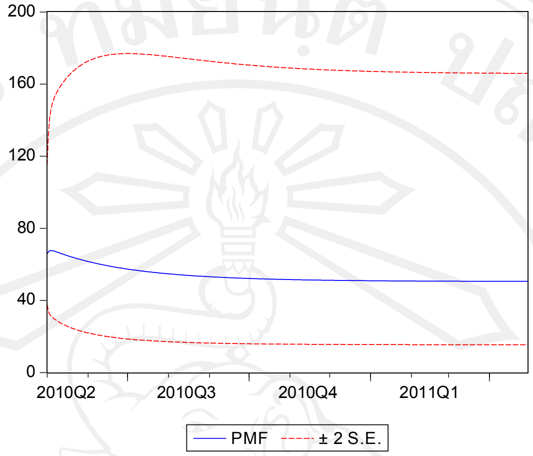


Source: calculation

Note: PM = Actual PM_{10} concentration, PMF = PM_{10} Forecast concentration

Figure 4.9 (b): Ex-post Forecast of PM_{10} Concentration from Model (4.2) (May 1st, 2009 – Apr 30th, 2010)

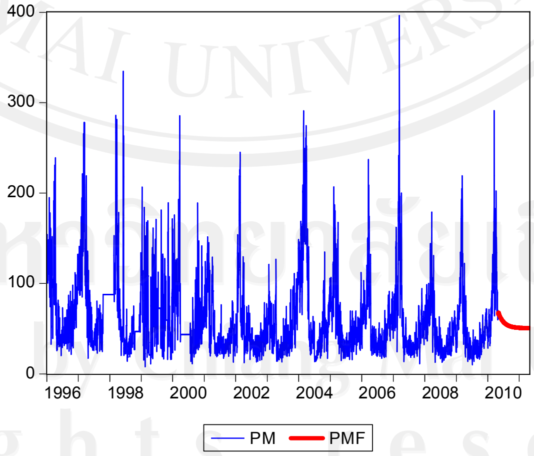
(iii) ***Ex-ante Forecast***: Model (4.1) is selected as the best fitted models for the forecast because of its minimum statistics RMSE from Historical and Ex-post Forecast. The forecast period is the next 365 days



Source: Calculation

Note: PMF = PM_{10} Forecast concentration

Figure 4.10: Forecast and S.E. of PM_{10} Concentration from Model (4.1) (May 1st, 2010-Apr 30th, 2011)



Source: Calculation

Note: PM = Actual PM_{10} concentration, PMF = PM_{10} Forecast concentration

Figure 4.11: Forecast of PM_{10} Concentration from Model (4.1) (May 1st, 2010 – Apr 30th, 2011)

4.5 Discussions

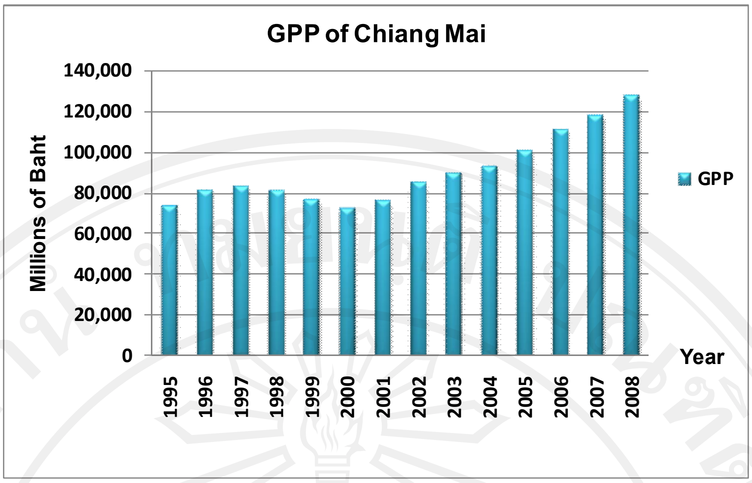
4.5.1 Survey of Environmental Kuznets Curve

Revisit the Time Series Curve of PM_{10} in Chiang Mai

According to the time series plots of PM_{10} monthly concentration in figure 4.2 (a) and the stationarity of data set from unit root test by Augmented Dickey-Fuller test, therefore, there is no trend in the data over the past 14 years. This suggests that the PM_{10}'s situation of Chiang Mai may be in either these three cases; (i) the stable peak of the Environmental Kuznets Curve (the inverted U-shaped curve), (ii) the stable peak or trough in the non-Environmental Kuznets Curve (N-shaped or J-shaped curve), or (iii) the PM_{10}'s pattern has been constant for a long time. The limited data available for this study do not permit us to choose between these three interpretations.

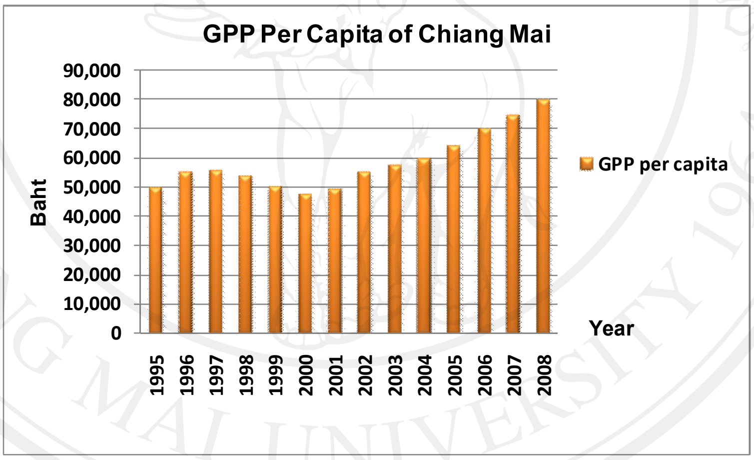
Structural Change Path Way of Chiang Mai

Panayotou (2003) divides the stage of economic development according to the Environmental Kuznets Curve hypothesis on the horizontal axis in three phases; (i) Pre-industrial economies (agriculture), (ii) Industrial economies, and (iii) Post-industrial economies (service), see figure 2.3 the integrated graph of Environmental Kuznets Curve Hypothesis. The GPP value and GPP per capita of Chiang Mai province is shown in figure 4.14 and 4.15 below respectively. In general, we can see the positive economic growth of Chiang Mai, although there's the decrease in 1998-2000 after the financial and economic collapse in Thailand before recovery in 2001.



Source: Calculation

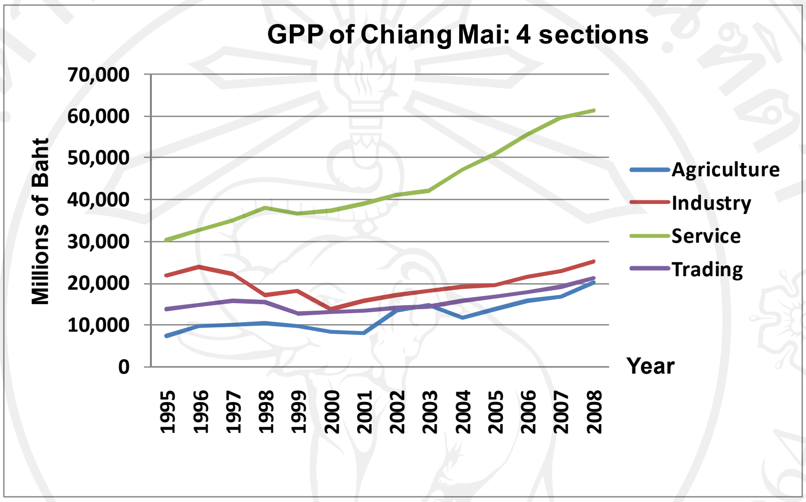
Figure 4.12: Gross Provincial Product (GPP) of Chiang Mai from 1995-2008



Source: Calculation

Figure 4.13: Gross Provincial Product (GPP) Per Capita of Chiang Mai from 1995-2008

The above GPP can be demonstrated as the economic structure, thus, four sections are divided for this study in order to consider the real production and activity in the province; (i) Agriculture, (ii) Industry, (iii) Service, and (iv) Trading. Agriculture section includes agriculture, hunting, forestry, and fishing. Industrial section includes mining, electricity, gas and water supply, and construction. Service section includes hotels and restaurants, transport, storage and communications, financial intermediation, real estate, renting and business activities, public administration and social securities, education, health and social work, social and personal service activities. Trading section includes wholesale and retail trade. The historical data reveals that the structural change path way is moved from agricultural section to service section along the economic development.



Source: Calculation

Figure 4.14: Gross Provincial Product (GPP) of Chiang Mai from 1995-2008

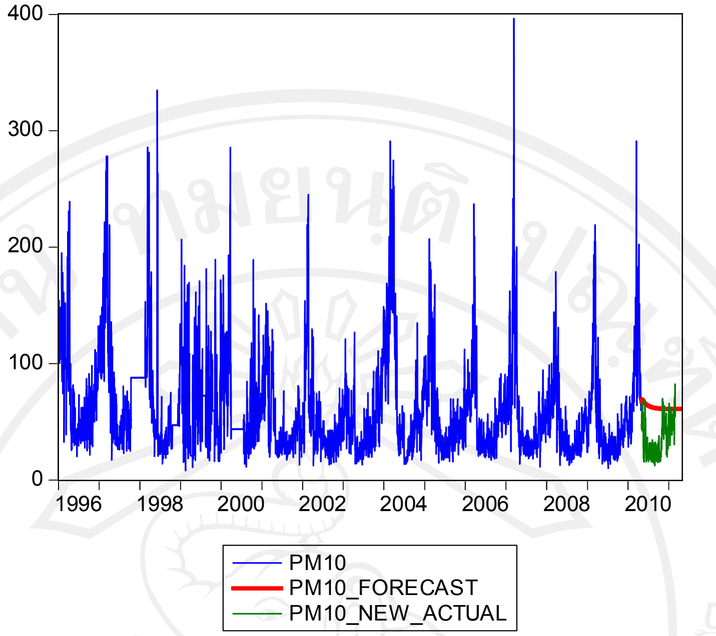
Indeed, Chiang Mai is not running the manufacturing as the major production as well as Phuket while these places are also recognized by both Thai people and foreigners as the popular tourist locations. This result may contradict to the concept of stages of economic development in Environmental Kuznets Curve hypothesis by Panayotou at the stable peak of inverted U-shaped curve.

The Difficulty in Demonstrating a Relationship

The relationship between environmental degradation (air pollutants, waste water, deforestation rate, municipal waste, energy consumption, or any other environmental pressures) and economic development in the various studies may appear in the different curves due to the diversity of measures of environmental quality. Besides the mixed results, the difficulty in demonstrating this relationship may lack of international environmental data as well as the heterogeneity of the elements of environmental quality. Economic growth for poorer countries may lead to improved water quality but increasing air pollution, for richer countries, growth may lead to improved air quality but more resource depletion. More importantly, in term of international trade, the richer countries may export the polluting industries to the poorer countries rather than reduce the total pollution per capita for the world. Due to the advantage of low labor cost and more available natural resources in Asia, there are more industrial productions and finished products are forwarded to America, Europe, and etc. for their consumptions. Industrial pollutions and wastes are left after production, natural resources are depleted while technological knowledge or trademarks are own by the richer countries who may gain much more than the producer. Moreover, actions in one country may cause consequences in another country as well as the global cooperation in conference direct forces the Annex I countries and non-Annex I indirectly. Thus, all of the difficulty above may results in the different curves and different orientation (globally or locally).

4.5.2 Recent Situation of PM_{10} in Chiang Mai

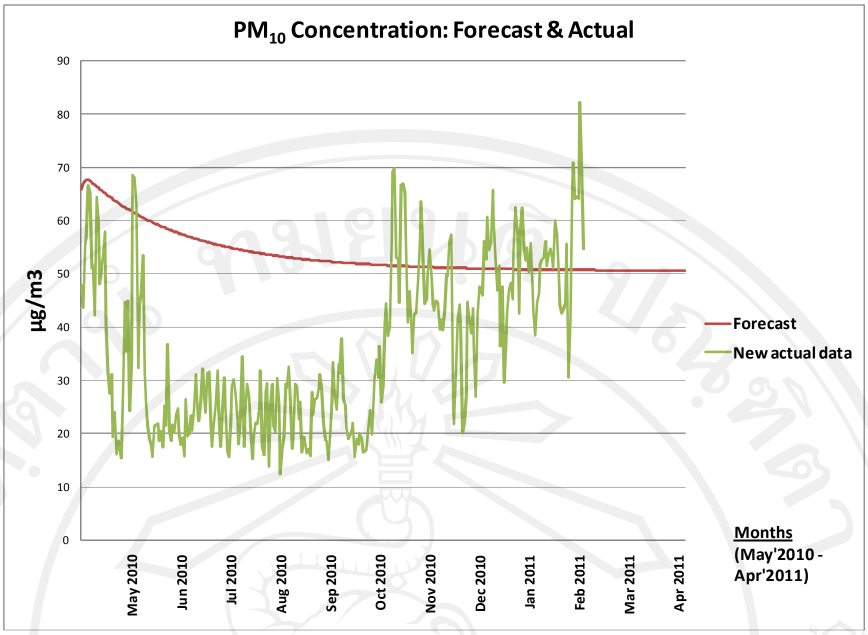
The original data set of daily air pollution concentration from PCD for the study is from January 1996-April 2010, this is employed in the analysis through the main objectives. After the completion of forecast section in ARMA modeling, there is a nice chance to further obtain the new data of PM_{10} concentration from PCD; this new data set is recorded from May 2010-February 2011. We aim to use this data set for comparison with the forecast line of the next 365 days from ARMA modeling (May 2010-April 2011). This latest data of PM_{10} actual concentrations of further ten months is added to the original daily data set continuously in the figure below.



Source: Calculation

Figure 4.15: PM_{10} Concentration: Historical, Forecast, and New Actual Data

In order to look deeper in the new data set, see the figure below for the daily PM_{10} concentrations from May 1st, 2010 to Apr 30th, 2011 in the green line compare to the forecast from ARMA process in red line. Apparently, the actual concentrations are within the +/- two S.E. interval of forecast concentrations.



Source: Calculation

Figure 4.16: PM_{10} Concentration: Forecast and New Actual Data (From May 1st, 2010 to Apr 30th, 2011)

PCD reported during December 2010 to January 2011 that the particulate matter problem from smoke and forest fires, open burning in the agriculture area, and rubbish burning in the upper northern area (in eight provinces) are still the major problem, especially during January-March every year. There is the "Stop Burning for Reducing Global Warming" Project to dedicate for His Majesty who has worked on the natural resources and environment conservation all along and to stop critical smoke problem in the northern area, this project is promoted by the Ministry of Natural Resource and Environment in January 19th, 2010. Anyhow, the project aims to reduce all kinds of burning, this emphasizes that the ministry has realized on the smoke problem.

In addition, PCD has implemented the air pollution management in the emission control and reduction by source in the vehicles, construction sites, and open burning areas. The focused areas that need the continuous solution are Bangkok, Samutprakarn, Saraburi, Rayong, and Chiang Mai. This includes the air pollution control in the urban area (especially in the big cities), inspection the vehicles that emit the pollution over the standard, promoting the preventive maintenance system for engines in transport and public vehicle sections, implement the measures to control the dust from constructions, cleaning the roads, to solve the pollution problem in the industrial areas, the smoke problem and forest fires, to conduct the public cooperation in stop open burning and develop the air pollution and smoke monitoring and warning system.

4.5.3 Major Sources of PM_{10} and smoke problem in Chiang Mai

The major sources of particulate matter and smoke problem in Chiang Mai could be these followings. (1) Agricultural burning, the reasons for farmers to use fires in their agricultural areas are to burn off their residuals such as rice straw after harvest; although harvest begins in December but smoke takes about four months before dispersed (Hoare, 2004), to prepare the land before the new crop as some farmers believe that the remnants after burning help nourishing their soil and fires is cheap so this is a traditional practice of farmers to do this “swidden burning”, to make the fire stopper by burning all the edges of their field to avoid fires from out side, to collect some forest products such as Hed-Thob (a kind of mushroom) or Pak-Wan (a kind of herb) which are the Northern forest products that yield once a year so they can sell at high price and the local people believe that these products will grow more after burning and raining. (2) Household burning, such as the daily activities in cooking, waste burning (rubbish, dried leaves, etc.) these activities may be found more in the urban area. More importantly, household burning appears all along the year. (3) Cattle burning by grazer who burn the land to open grazing area with higher nutritive value. (4) Forest fires, this may occur naturally during the dry season or by un-intentionally man-made spreading out to forest areas such as from agricultural burning, cattle grazer burning, or roadside fires which is lit by a cigarette from driver who throw it away from his car. (5) Smoke Trans-boundary, northern Thailand may receive the smoke that is transported from neighbouring provinces or countries such as Burma, Laos, or China.

4.5.4 Potential Shocks of Smoke Problem in Chiang Mai

We have learned that the major causes of smoke problem in the Northern Thailand is from man-made activities, apparently, the deliberate burning from agriculture, cattle, and household. As the historical data of Chiang Mai's GPP from 1995-2008 shows the agricultural value is around 10% to 16%. Although this value does not move in high variation, but we do not prefer expanding in burning and promote to stop burning instead. Traditional practice of burning may requires more time for local people to understand and take the new practice without suffering from poverty-stricken living that we expect people to concern more on environment. Some industrial workers, general workers or merchants may return back to work in the farm, this case has a chance to be happened when there is the economic shock that causes the unemployment or layoff by the factories for workers and loss in business for merchants. We may link the economic or financial crisis in the past with the year having number of days of PM_{10} concentration that exceeds ambient air standard, see table below for summary.

Table 4.12: Summary in yearly basis: PM_{10} exceeds Ambient Air Standard and Important Situations

Year	No. of days (*)	Important Situations/Potential Shocks (**)
1996	56	N/A
1997	70	Asian Financial Crisis (Thailand's financial and economic collapse)
1998	38	N/A
1999	31	N/A
2000	32	Y2K
2001	10	911 (USA)
2002	23	N/A
2003	5	N/A
2004	84	Thailand Tsunami Disaster, Oil Price Crisis, Bird Flu Pandemic
2005	26	N/A
2006	17	Thai Coup d'etat
2007	38	Sub-Prime
2008	8	N/A
2009	22	2009 Flu Pandemic
2010	25	Dubai Financial Collapse

Source: (*) Calculation, (**) Wikipedia

The top of peak days is in 2004 when there was the Thailand Tsunami Disaster. More than thousand people in six Southern provinces (Sa-Toon, Trang, Kra-Bi, Pang-Nga, Phu-Ket, and Ra-Nong) were killed from the Tsunami disaster in December 26th, 2004. We can understand that the government put more budgets for treatment and recovery the people and places, some budget for development may be transferred to this purpose as well as the money from private section was also sent to the south. In addition, there are the oil price crisis and bird flu pandemic happened in the same year which cause the economic situation more severe.

There is the Asian financial crisis in 1997, this crisis started in Thailand with the financial collapse of the Thai baht called Tom-Yam-Kung. The past fixed exchange rate of peg to the USD at 25 baht/USD was changed to floating rate at about 40+ baht per USD (lowest depreciation at 55 baht per USD). Many businesses have to be closed down due to loss from high debt, workers were layoff, the government was forced to resign, and The International Monetary Fund (IMF) stepped in to initiate a USD 40 billion program to stabilize the currency.

Further more, the Y2K, 911 in USA, Thai Coup d’etat, Sub-Prime in USA, 2009 Flu Pandemic, and Dubai Financial Collapse respectively from the above table, these may be the shocks of environmental degradation. These situations may cause more farmers during the economic crisis. Political shock could be another factor apart from economic shock that could effect to the labor transfer from non-agricultural to agricultural section and produce more smoke from unnecessary burning activities.