International Journal of Emerging Technology and Advanced Engineering
Website: www.ijetae.com (E-ISSN 2250-2459, UGC Approved List of Recommended Journal)
Volume 7, Special Issue 1, September 2017

Forecasting Air Quality In Ernakulam District, Kerala, India
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Abstract: This study aims to forecast air quality in terms of Air Quality Index as per National Air Quality standards based on the database monitored at different air quality monitoring stations in Ernakulam District. Air Quality Index was determined using US Environmental Protection Agency procedure and National Air Quality Index Standards as per Central Pollution Control Board, India. Holt Winter’s exponential smoothing technique was selected and the computations involved in this study have been done by using MiniTab 17 (Version: 17.3.1) and R Software (Version: 3.3.2). Air quality in Ernakulam District is deteriorating at a consistent rate and from the Air Quality Index (AQI) values, the most responsible pollutant for the change is in air quality in Ernakulam district is respirable suspended particulate matter. In 2012, an AQI of 316 was observed in Irumpanam region and air quality in Irumpanam region deteriorates from July, 2013 to September, 2014. After that a sudden decrease in AQI was observed in 2015. From these, we can say that among the seven stations in Ernakulam district, Irumpanam station is the most important area were the rapid deterioration and restoration of air quality is occurring, mainly due to respirable suspended particles. But in September 2015 and December 2015, the data from two stations i.e. Methanam and TCC Elloor showed that the AQI results were satisfactory and pollutant responsible for that was NO2. Forecasting using Holt Winter’s method provided satisfactory results. Based on the forecast, this Holt Winter’s method is capable in monitoring and forecasting the ambient air quality. Deterioration of air quality is an important issue faced by many cities in India. Forecasting air quality can create awareness among citizens about the associated health impacts due to air pollution exposure and to assist the public in air quality data interpretation and decision making processes related to air pollution mitigation measures.

Keywords: Air Quality Index, Air Quality, Exponential Smoothing, Holt-Winters Method, Forecasting, Time Series Analysis

I. INTRODUCTION

Deterioration of air quality is an important issue faced by many cities in India. The state of air around us and the quality of outdoor air in our surrounding environment can be termed or referred as air quality and ambient air quality respectively. The increase in the number of vehicles, unrestrained burning of plastics, unacceptable construction and industrial activities are the main reasons for this deterioration. Air pollutants like Particulate matter (PM10 and PM2.5), Gases (Nitrogen oxides, Sulphur oxides, Hydrocarbons, and Carbon monoxide), Radioactive materials etc. present in certain concentrations can create adverse problems on plants, animals, human beings and this atmospheric condition can be defined as air pollution. It’s one of the major issues affecting the environment or our ecosystem, agricultural crops etc. Apart from the above mentioned issues, air pollution can cause serious damages to buildings, sculptures and vegetation. Vehicular emissions are rising rapidly and it is the main contributor of air pollution. Due to the increased industrial emissions, vehicular emissions and emissions from the combustion process, the air quality in urban regions are deteriorating at a higher rate than in the rural regions. As a result, air quality in many Indian cities has negative health effects on the exposed inhabitants. This decrease in air quality can cause allergies, asthma, cancers, diseases and death to human beings and damage to plants and animals.

Forecasting of air pollutants in terms of Air Quality Index (AQI) is an essential task in the process of evaluating and taking regulatory measures in an urban area. So far, various tools have been implemented by different researchers in order to have the consistent forecasts of air pollutants. To form better air quality and making future planning, AQI approach can be adopted in air quality management. With the previous AQI values, the variations in air quality can be easily identified. Due to this reason many researches were conducted with respect to the air quality mainly focusing on the main air pollutants (CO, NO2, SO2, O3, PM10 and PM2.5). Forecasting helps to alert the authorities, industries etc. in order to take necessary actions and steps to improve the quality of air. Also by forecasting, current and future air quality details can be conveyed to the general public in a simple way. In most of the air quality related research works, Gaussian dispersion models were used in the prediction of air quality. Although these model have a physical base, the information related to source of pollutants and various pollutants were unidentified. Several time series models are available and the existing time series forecasting accuracy is consistent to many decision making processes.

For the public to straightforwardly be aware of how bad or good air quality and to help in data interpretation for decision making processes related with air quality management and pollution mitigation measures, AQI is asignificantpart. In this study, Holt Winter’s exponential smoothing has been used to analyze and

International Conference on Innovative Developments in Engineering & Applied Sciences (IDEAS)-2017 Organized by UKF College of Engineering & Technology, Parippally, Kerala, India | 96
forecast the varying trends of air quality in terms of AQI in Ernakulam District, Kerala, India based on the database monitored at different air quality monitoring stations during the period of 2012-2015. 

II. MATERIALS AND METHOD

2.1 Study Area

Ernakulam is a district of Kerala shown in [Fig. 1]; India formed on 1 April 1958 is situated in the central part of Kerala state. Ernakulam is spread over 3068 km² with 12% of Kerala’s population and is located on the western coastal plains of India. Ernakulam district is divided into three parts viz. lowland, midland and highland comprising of seaboard, plains, hills and forests respectively. According to 2001 census, the residential population of Ernakulam was 3,105,798 and it was listed as the most advanced district in Kerala12. In terms of Gross Domestic Product (GDP) and per capita income Ernakulam district is the ironic district in Kerala. It is one of the busiest and polluted districts in Kerala. Due to the increasing air pollution, Ernakulam district consists of seven air quality monitoring stations and they are classified into residential, rural, sensitive and industrial category, summarized in [Table 1]. All these stations are controlled by Kerala State Pollution Control Board (KSPCB) and the stations are Methanam, TCC Elloor, South Over Bridge, Irumpanam, Kalamassery, MG Road and Vyttila13.

![Map showing study area Ernakulam District, Kerala, India](Map Data ©2017 Google Maps)

Fig. 1 Map showing study area Ernakulam District, Kerala, India

Table 1 Air quality monitoring stations in Ernakulam District, Kerala, India13

<table>
<thead>
<tr>
<th>Station</th>
<th>Type</th>
<th>Latitude</th>
<th>Longitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanam</td>
<td>Residential</td>
<td>10°04'296&quot;N</td>
<td>76°18'238&quot;E</td>
</tr>
<tr>
<td>TCC Elloor</td>
<td>Industrial</td>
<td>10°04'313&quot;N</td>
<td>76°18'097&quot;E</td>
</tr>
<tr>
<td>South Over Bridge</td>
<td>Residential, Rural &amp; Others</td>
<td>09°57'09&quot;N</td>
<td>76°17'57&quot;E</td>
</tr>
<tr>
<td>Vyttila</td>
<td>Residential, Rural &amp; Others</td>
<td>09°57'49&quot;N</td>
<td>76°19'05&quot;E</td>
</tr>
<tr>
<td>Irumpanam</td>
<td>Industrial</td>
<td>09°59'26&quot;N</td>
<td>76°21'01&quot;E</td>
</tr>
<tr>
<td>Kalamassery</td>
<td>Industrial</td>
<td>10°03'14&quot;N</td>
<td>76°18'44&quot;E</td>
</tr>
<tr>
<td>MG Road</td>
<td>Residential &amp; Others</td>
<td>09°58'29&quot;N</td>
<td>76°17'31&quot;E</td>
</tr>
</tbody>
</table>

2.2 Air Quality Data

In this study, the monthly air quality data of Nitrogen dioxide (NO₂), Sulphur dioxide (SO₂), Suspended particulate matter (SPM) and Respirable particulate matter (RSPM) over a period of 2012-2015 at seven stations in Ernakulam District, obtained from Kerala State Pollution Control Board has been used.

2.3 Holt-Winters Method

Holt-Winters model or method was first proposed in the early 1960s. It is based on the exponential smoothing technique. Single exponential smoothing is the simplest form of exponential smoothing technique and it can be used for time series data without any trend or seasonal component. Holt-Winters method can deal with time series data having trend and seasonal component and all the time series data values contributes to the calculation of the prediction model. This method can be classified into two i.e. additive method and
multiplicative method. Holt-Winters method uses a modified form of exponential smoothing and applies three exponential smoothing formulae to the time series. Initially, the mean or level of the time series data is smoothed to give a local average value for the time series and then the trend of the time series is smoothed. Finally, each seasonal sub-index i.e. all data for January, all data for February, all data for March, all data for April etc. (monthly data) is smoothed separately to give a seasonal estimate for each of the seasons.  

2.4 Methodology

The purpose of this study is to analyze and forecast the air quality index using the Holt Winter’s exponential smoothing technique. Because of the effective results in forecasting field, a lot of researchers use various forecasting techniques. Air quality index is calculated based on the AQI formula as below:

\[
I_p = \left( \frac{(I_{Hi} - I_{Lo})}{(BP_{Hi} - BP_{Lo})} \right) [C_p - BP_{Lo}] + [I_{Lo}] \quad ... (1)
\]

where 
- \(I_p\) Individual AQI for pollutant ‘P’
- \(C_p\) Daily mean concentration of pollutant ‘P’
- \(I_{Hi}\) Sub index value or individual AQI value corresponding to \(BP_{Hi}\) (Table 2)
- \(I_{Lo}\) Sub index value or individual AQI value corresponding to \(BP_{Lo}\) (Table 2)
- \(BP_{Hi}\) Breakpoint or nearby higher value greater than or equal to \(C_p\) in Table 2
- \(BP_{Lo}\) Breakpoint or nearby lower value less than or equal to \(C_p\) in Table 2

Table 2 Proposed sub-index and breakpoint pollutant concentration for Indian air quality index (24 hr. avg.)

<table>
<thead>
<tr>
<th>Sl. No.</th>
<th>(SO_2)</th>
<th>(NO_2)</th>
<th>(PM_{2.5})</th>
<th>(PM_{10})</th>
<th>Index values</th>
<th>Descriptor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 - 40</td>
<td>0 - 40</td>
<td>0 - 30</td>
<td>0 - 50</td>
<td>0 - 50</td>
<td>Good</td>
</tr>
<tr>
<td>2</td>
<td>41 - 80</td>
<td>41 - 80</td>
<td>31 - 60</td>
<td>51 - 100</td>
<td>51 - 100</td>
<td>Satisfactory</td>
</tr>
<tr>
<td>3</td>
<td>81 - 380</td>
<td>81 - 180</td>
<td>61 -90</td>
<td>101 - 250</td>
<td>101 - 200</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>381 - 800</td>
<td>181 - 280</td>
<td>91 - 120</td>
<td>251 - 350</td>
<td>201 -300</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td>801 - 1600</td>
<td>281 - 400</td>
<td>121 - 250</td>
<td>351 - 430</td>
<td>301 - 400</td>
<td>Very poor</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 1600</td>
<td>&gt; 400</td>
<td>&gt; 250</td>
<td>&gt; 430</td>
<td>&gt; 400</td>
<td>Severe</td>
</tr>
</tbody>
</table>

In Holt-Winters multiplicative method, the exponential smoothing formulae applied to a time series with trend and constant seasonal component are:

\[
a_t = \alpha (Y_t - s_{t-p}) + (1 - \alpha)(a_{t-1} + b_{t-1}) \quad ...(2)
\]

\[
b_t = \beta (a_t - a_{t-1}) + (1 - \beta)b_{t-1} \quad ...(3)
\]

\[
s_t = \gamma (Y_t - a_t) + (1 - \gamma)s_{t-p} \quad ...(4)
\]

where, \(\alpha, \beta, \gamma\) are the smoothing parameters
- \(a_t\) is the smoothed level at time \(t\)
- \(b_t\) is the change in trend at time \(t\)
- \(s_t\) is the seasonal smooth at time \(t\)
- \(p\) is the number of seasons per year

Holt-Winters method procedure requires initializing or starting values and this can be obtained by using:

\[
a_p = \frac{1}{p} (Y_1 + Y_2 + ... + Y_p)
\]

\[
b_p = \frac{1}{p} \left( \frac{Y_{p+1} - Y_1}{p} + \frac{Y_{p+2} - Y_2}{p} + ... + \frac{Y_{p+p} - Y_p}{p} \right)
\]

\[
s_1 = Y_1 - a_p, s_2 = Y_2 - a_p, ..., s_p = Y_p - a_p
\]

Forecast values using Holt-Winters method can be calculated using the latest estimates from the appropriate exponential smooths that have been applied to the time series data. Forecast for the time period \(T+\tau\) is:

\[
\hat{Y}_{t+\tau} = a_T + \tau b_T + s_T \quad ...(5)
\]

where, \(a_T\) is the smoothed estimate of the level at time \(T\)
- \(b_T\) is the smoothed estimate of the change in trend value at time \(T\)
- \(s_T\) is the smoothed estimate of the appropriate seasonal component at time \(T\)

In Holt-Winters multiplicative method, the exponential smoothing formulae applied to a time series with trend and constant seasonal component are.
\[ a_t = \alpha \frac{Y_t}{s_{t-p}} + (1 - \alpha)(a_{t-1} + b_{t-1}) \]  
\[ b_t = \beta (a_t - a_{t-1}) + (1 - \beta) b_{t-1} \]  
\[ s_t = \gamma \frac{Y_t}{a_t} + (1 - \gamma)s_{t-p} \]

where, \( \alpha, \beta, \gamma \) are the smoothing parameters  
\( a_t \) is the smoothed level at time \( t \)  
\( b_t \) is the change in trend at time \( t \)  
\( s_t \) is the seasonal smooth at time \( t \)  
\( p \) is the number of seasons per year

Holt-Winters method procedure requires initializing or starting values and this can be obtained by using:

\[
a_p = \frac{1}{p} \left( Y_1 + Y_2 + \ldots + Y_p \right)
\]
\[
b_p = \frac{1}{p} \left( \frac{Y_{p+1} - Y_1}{p} + \frac{Y_{p+2} - Y_2}{p} + \ldots + \frac{Y_{p+p} - Y_p}{p} \right)
\]
\[
s_p = \frac{Y_1}{a_p}, s_2 = \frac{Y_2}{a_p}, \ldots, s_p = \frac{Y_p}{a_p}
\]

Forecast for the time period \( T+t \) is:

\[
\hat{Y}_{t+t} = (a_t + tb_t)s_t \]

where, \( a_t \) is the smoothed estimate of the level at time \( T \)  
\( b_T \) is the smoothed estimate of the change in trend value at time \( T \)  
\( s_T \) is the smoothed estimate of the appropriate seasonal component at time \( T \)

In this study, air quality data of SO\(_2\), NO\(_2\), RSPM and SPM over a period of 2012-2015 at Ernakulam District, obtained from Kerala State Pollution Control Board (KSPCB) has been used. The computations involved in this study have been computed by using Minitab 17 (Version: 17.3.1), R Software (Version: 3.3.2). Smoothing parameters were obtained from R Software and the remaining computations were done using Minitab 17.

2.5 Accuracy Measures

Models performance was identified using the Mean Absolute Deviation (MAD), Mean Absolute Percentage Error (MAPE) and Mean Squared Displacement (MSD).

III. RESULTS AND DISCUSSION

AQI is determined by selecting the maximum operator scheme, i.e. out of all the considered pollutants, the maximum sub-index value becomes the overall index or air quality index. The air quality data from the Kerala State Pollution Control Board shows that the responsible pollutant for AQI in all these stations is respirable suspended particulate matter (RSPM) due to its abundance in the atmosphere. From the AQI calculation, the air quality for the year 2014 in the station Irumpanam was moderate with an average value of 132. Since Irumpanam and the surrounding locations consists of several industries, the AQI from 2012-2015 varies from good to very poor conditions. In 2012, an AQI of 316 was observed in Irumpanam region and the AQI in Irumpanam region increased (deteriorates) from July, 2013 to September, 2014. After that a sudden decrease in AQI was observed in 2015. From these, we can say that among the seven stations in Ernakulam district, Irumpanam station is the most important area were the rapid deterioration and restoration of air quality is occurring, mainly due to respirable suspended particles. But in September 2015 and December 2015, the data from two stations i.e. Methanam and TCC Elloor showed that the AQI results were satisfactory and pollutant responsible for that was NO\(_2\). The time series plots of air quality index of the seven stations are shown in [Fig. 2 to 8].
Fig. 2 AQI from 2012-2015, Station: Methanam

Fig. 3 AQI from 2012-2015, Station: TCC Elloor

Fig. 4 AQI from 2012-2015, Station: Vyttila
Fig. 4 AQI from 2012-2015, Station: Vyttila

Fig. 5 AQI from 2012-2015, Station: Irumpanam

Fig. 6 AQI from 2012-2015, Station: Kalamassery
Air quality index in Ernakulam District is within the good and moderate range. Poor air quality index was reported on the station Irumpanam during September 2012, November 2013 and July 2014. Time series plot showed that data is non-stationary in all cases and data pattern in TCC Elloor and Vyttila stations showed a seasonal pattern. Forecasts are shown in Fig. 9 to 15.
Fig. 10 AQI forecast for 2016, Station: TCC Elloor

Fig. 11 AQI forecast for 2016, Station: Vytilla
Fig. 12 AQI forecast for 2016, Station: Irumpanam

Fig. 13 AQI forecast for 2016, Station: Kalamassery
IV. CONCLUSION

In this study, Holt Winter’s method was used to analyse and forecast air quality index in Ernakulam District, Kerala, India. Generally, the air quality index recorded at all stations between the years 2012-2015 varies from moderate to very poor AQI range. Mean of
the air quality index recorded in all stations were satisfactory and the major pollutant in the area is respirable suspended particulate matter. Effect and concentrations of Sulphur dioxide and Nitrogen dioxide recorded at all the stations were well below the limits. But in September 2015 and December 2015, the pollutant responsible for AQI was NO₂ in two stations i.e. Methanam and Irumpanam. In most stations the responsible pollutant for the deterioration of air quality is respirable suspended particulate matter.

From the results, this method provided satisfactory results and has been proven more effective in forecasting and analysing air quality index. But the models developed using Holt Winter’s method are not able to recreate spatial situation despite the fact that they are very useful in prediction of future air quality. It can be improved further by considering other types of pollutants and the meteorological variables. It is expected that the incorporation of these variables may improve the prediction ability of the air quality models.

V. REFERENCES


[12]. District Profile of Ernakulam, Official Website of Ernakulam District Administration, http://ernakulam.nic.in. Date accessed: 10/01/2017


[16]. CPCB National Air Quality Index Report, PR Division, Delhi, 2014.