Impact of Crude Oil Consumption on Deaths Due to Air Pollution in India: A Forecasting Approach

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Abstract

India's rank in crude oil consumption is third after USA and China. A high quantity of diesel (70%) and petrol (99.6%) is consumed in the transportation sector. As per reports transportation sector contributes 29% of t air pollution. Due to air pollution In 2019 in India, 1.6 million people died. In this work, correlation analysis is performed to find the dependency of casualties due to air pollution on crude oil consumption and registered vehicles in India. Historical data on crude oil consumption, registered vehicles, and casualties due to air pollution are analyzed to predict casualties due to air pollution. Using HoltWinters and ARIMA models. A high positive correlation (0.9) is found between deaths and crude oil consumption and registered vehicles in India. Using the ARIMA models predicted values for crude oil consumption and registered vehicles in India for 2030 are found 7.39 million barrels per day and 550.8 million respectively. These values are used for the regression model to predict deaths due to air pollution and expected deaths due to air pollution were found in 2085938 for 2030.

Keywords: Crude oil consumption, Vehicles, Deaths due to air pollution, HoltWinters, ARIMA.

Introduction

In 2019 the registered vehicles in India were 295.8 million, which was 48 million in 2000. Registered vehicles in India are increased by 500% in the last twenty years. In 2019 daily crude oil demand of India was 5.14 million barrels per day which was 2.28 million barrels per day in 2000. The crude oil demand in India is increased by 125 % in the last twenty years. A maximum part of the crude oil is consumed in the transportation sector. 99.6 % of petrol and 70 % of diesel is consumed in the transportation sector. High consumption of diesel and petrol damage air

quality as 29 % of air pollution is due to the transportation sector in India. Air pollution causes so many incurable and fatal diseases. As per reports worldwide deaths due to air pollution in 2019 were 6.7 million. In 2019 causalities due to air pollution in India were 1.6 Million. 30 % of deaths in India are only due to air pollution. As per reports of business today 2.5 million people die each year due to air pollution only and 30 % of deaths are due to fossil fuel only. Looking for a high negative impact of crude oil consumption forecast models are developed to predict crude oil demand and registered vehicles in India. A regression model is also developed to predict casualties due to air pollution in India where deaths are considered dependent on crude oil consumption and registered vehicles in India.

Balakrishnan, et al. (2019) studied the casualties due to air pollution and Pm 2.5 level in India. They found that no Indian state has less than Pm 2.5 level 10 $\mu g/m^3$ recommended by WHO and more than 70% population of India is facing PM 2.5 more than 40 $\mu g/m^3$. They found that the burden of deaths of the person of age less than 70 years is 8%. They found that expected deaths due to air pollution in 2017 will be 1.7 million out of which 0.67 million is due to ambient air pollution.

Pandey et al. (2021) expected 1.67 deaths due to air pollution in India. Mukhopadhyay, & Forssell, (2005), Anenberg, et al.(2019), and Guttikunda et al. (2014) found that the transportation sector is the reason for air pollution in thirty-seven cities of India. They found that despite the efforts of regulatory bodies transportation sector will be a cause of major health risks due to air pollution globally. Anwar, et al. (2021) found that fossil fuels have a significant contribution to air pollution in India, Pakistan, and China. Owusu, & Sarkodie, (2020) examined twenty-eight years of data to find the impact of ambient air pollution on casualties in India, China, Japan, Russia, Germany, and JAPAN. They found that in these countries ambient air pollution has a significant effect on premature deaths and economic welfare costs. Guttikunda, & Nishadh, (2022) found that due to the rapid increase in demand for vehicles, BHARAT-VI standards gains vanished to control air pollution due to the transportation sector. Tripathi, & Pathak, (2021) forecasted air pollution using deep learning concepts. Maji, et al. (2017) analyzed data from 1992 to 2013 to find the impact of air pollution on human health in Mumbai. They found that various cases of fatal diseases increased in these twenty-two years. Tobollik, et al. (2015) studied for deaths of people more than the age of 30 years due to ambient air pollution in Kerala. Sahu, & Kota (2017) found that almost 90% of the day capital of India is highly air polluted. Premature mortality due to air pollution in India is studied by Nair et al. and Ghude, et al. (2016). Manoj Kumar, & Srimurug Anandam, (2021) found that in 2017, 127014 deaths were due to air pollution only and in the cities with high PM 2.5 more patients were admitted to the hospitals. Vohra, et al. (2021) found that fossil fuel highly contributes to PM2.5 and causes a huge number of mortalities due to air pollution. They estimated per year the death of 10.2 million people due to air pollution. They estimated 2.5 million casualties due to air pollution in India. Turner, et al. (2020) found a relationship between ambient air pollution due to fossil fuel. They

found thousands of lung cancer cases and deaths due to ambient air pollution. Taghizadeh-Hesary, & Taghizadeh-Hesary, (2020) studied lung cancer due to air pollution and the contribution of fossil fuels to air pollution in Southeast Asia. Maciejczyk, et al.(2021) and Wu, et al.(2023) studied the contribution of the transportation sector to air pollution. Yun, X., et al.(2020) studied deaths due to energy sources and their contribution to air pollution in China. Khandker, et al.(2022) studied air pollution due to fossil fuel in Bangladesh. Sial, et al. (2022) analyzed data from 1996 to 2019 to find the casualties due to air pollution due to fossil fuels in Asian countries. Brumberg, et al.(2021) studied that pediatric health is highly affected by air pollution. Liu, et al.(2022) studied ambient air pollution in Mongolia.

Material and Methods:

In this section, forecasting models will be developed to predict crude oil consumption and registered vehicles in India using R software. A regression model is also developed to predict deaths due to air pollution, considering dependent on crude oil consumption and registered vehicles in India. Since 2020 and 2021 were highly affected by COVID, historical data from the years 2010 to 2019 is considered to develop the prediction models.

Historical data of daily crude oil consumption (million barrels per day), number of registered vehicles (million), and deaths due to air pollution in India

Table - 1

Year	Crude oil demand	Registered vehicles	Deaths due to air pollution
2010	3.308	127.746	1459000
2011	3.475	141.866	1498000
2012	3.674	159.491	1541000
2013	3.717	176.044	1585000
2014	3.832	190.704	1592000
2015	4.147	210.023	1608000
2016	4.544	230.031	1600000
2017	4.724	253.311	1604000
2018	4.974	272.587	1645000
2019	5.148	295.772	1667000

Source: ycharts.com
Source: www.statista.com

Correlation analysis

The correlation between casualties due to air pollution and crude oil consumption is found 0.945 and the correlation between casualties due to air pollution and registered vehicles is found 0.956. Since a high correlation is found between deaths due to air pollution and crude oil consumption and registered vehicle we can say that casualties due to air pollution are highly dependent on crude oil consumption and registered vehicles in India. A regression model will be developed to predict deaths due to air pollution considering dependent on crude oil consumption and registered vehicles.

Forecast analysis to predict crude oil consumption in India:

Prediction of crude oil consumption in India using the HoltWinters model

In this section, forecast analysis will be performed to predict daily crude oil consumption in India using HoltWinters and ARIMA models using R software. Figure 1 represents the actual crude oil consumption and predicted crude oil consumption by the HoltWinters model.

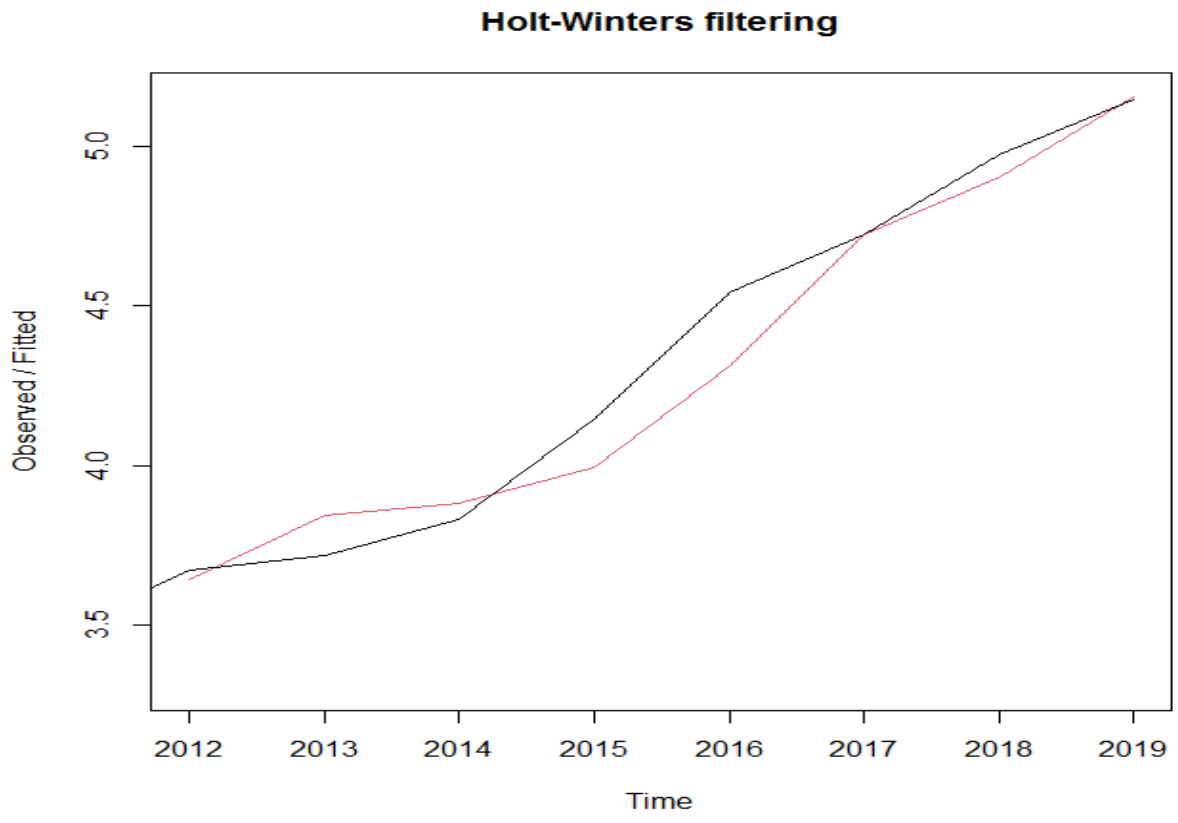

Figure 1: Comparative analysis of actual and predicted crude oil consumption in India by HoltWinters model.

Summary of HoltWinters model to predict crude oil consumption:

Forecast accuracy of HoltWinters model to predict crude oil consumption
Table - 2

ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
0.039	0.112	0.084	0.797	1.987	0.410	0.199

Forecasted crude oil consumption using HoltWinters model
Table - 3

Year	Forecast	LO 80	HI 80	LO 95	HI 95
2020	5.329	5.185	5.473	5.108	5.550
2021	5.510	5.301	5.718	5.190	5.829
2022	5.690	5.429	5.952	5.291	6.090
2023	5.871	5.563	6.180	5.400	6.343
2024	6.052	5.700	6.404	5.514	6.591
2025	6.233	5.839	6.627	5.631	6.835
2026	6.414	5.979	6.848	5.750	7.078
2027	6.595	6.121	7.068	5.870	7.319
2028	6.775	6.263	7.288	5.991	7.560
2029	6.956	6.405	7.507	6.113	7.799
2030	7.137	6.548	7.726	6.236	8.038

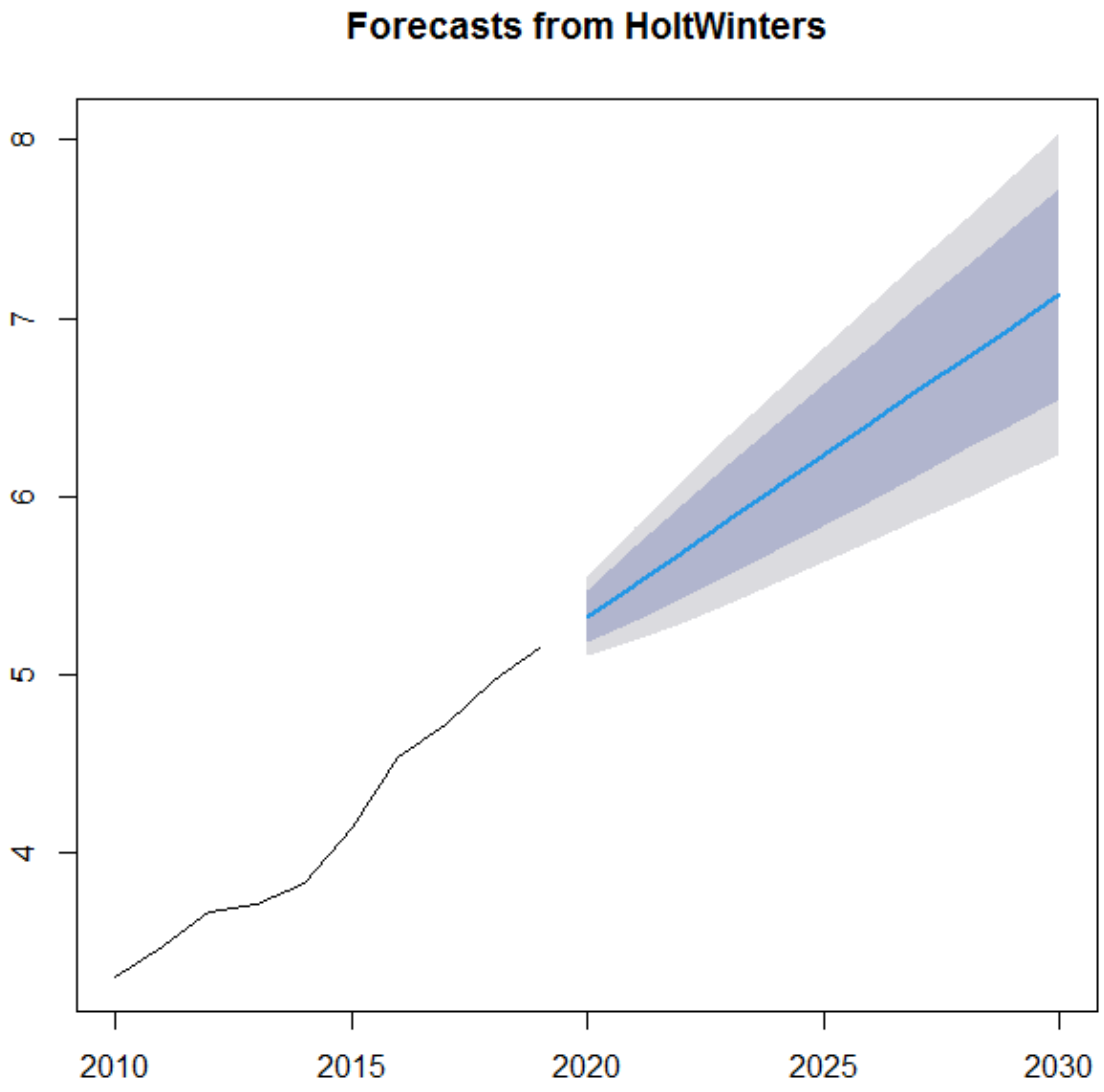

Figure 2: Forecast of crude oil consumption in India using HoltWinters model

Prediction of crude oil consumption in India using the ARIMA model

An ARIMA model is also developed to predict crude oil consumption in India. A summary of the ARIMA model is given below:

Summary of ARIMA model to predict crude oil consumption:

Forecast accuracy of ARIMA model to predict crude oil consumption
Table - 4

ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
0.000	0.094	0.070	-0.110	1.693	0.343	0.222

Forecasted crude oil consumption using ARIMA
Table - 5

Year	Forecast	LO 80	HI 80	LO 95	HI 95
2020	5.352	5.218	5.487	5.146	5.558
2021	5.557	5.366	5.747	5.266	5.848
2022	5.761	5.528	5.995	5.404	6.118
2023	5.966	5.696	6.235	5.554	6.378
2024	6.170	5.869	6.471	5.710	6.631
2025	6.375	6.045	6.705	5.870	6.879
2026	6.579	6.223	6.936	6.034	7.124
2027	6.784	6.403	7.165	6.201	7.366
2028	6.988	6.584	7.392	6.370	7.606
2029	7.192	6.766	7.618	6.541	7.844
2030	7.397	6.950	7.844	6.714	8.080

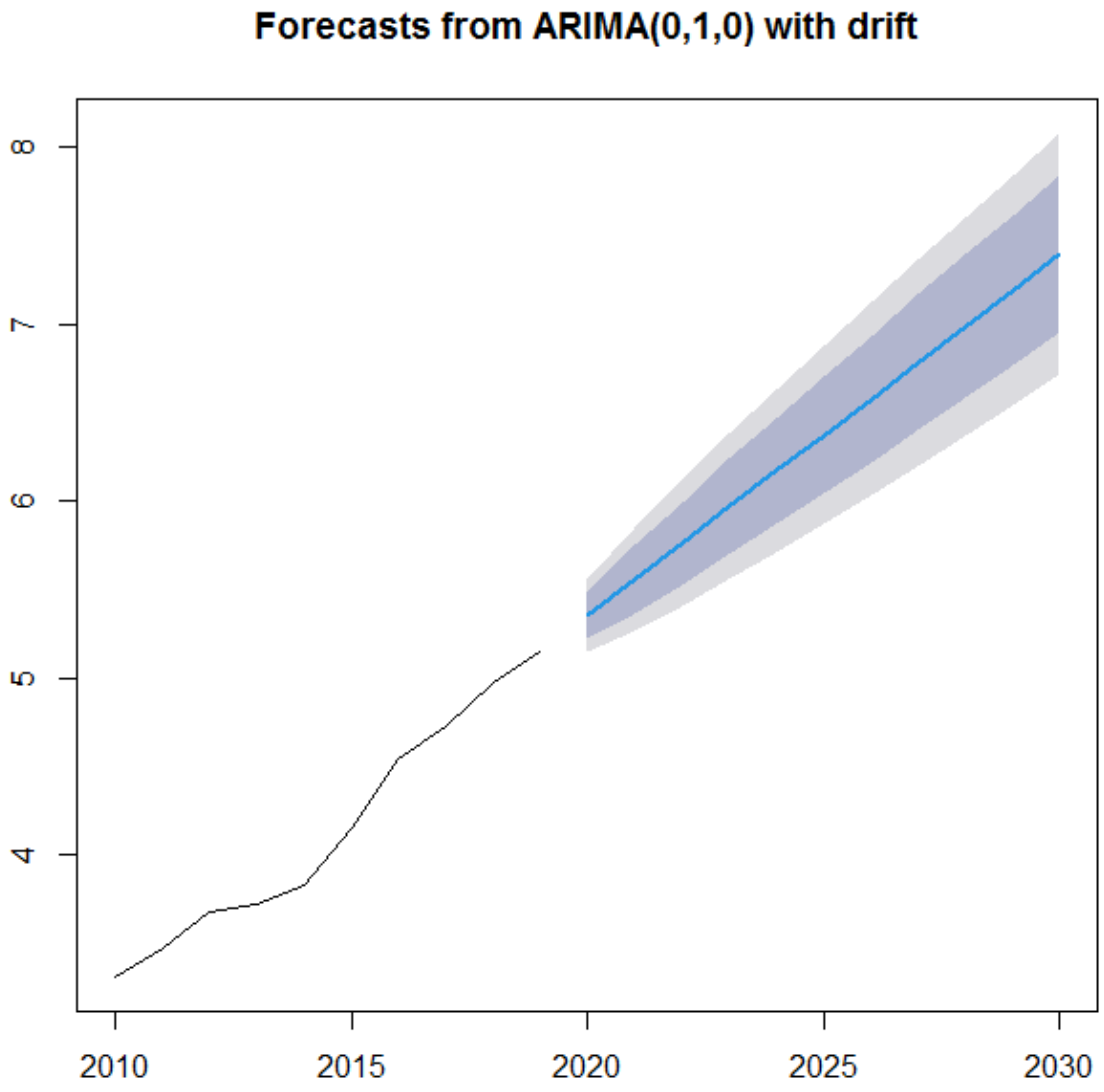

Figure 3: Forecast of crude oil consumption in India using the ARIMA model

Forecast analysis to predict registered vehicles in India:

In this section, forecast analysis will be performed to predict yearly registered vehicles in India using HoltWinters and ARIMA models using R software.

Prediction of registered vehicles in India using the HoltWinters model

Figure 4 represents the actual registered vehicles and predicted registered vehicles by the HoltWinters model.

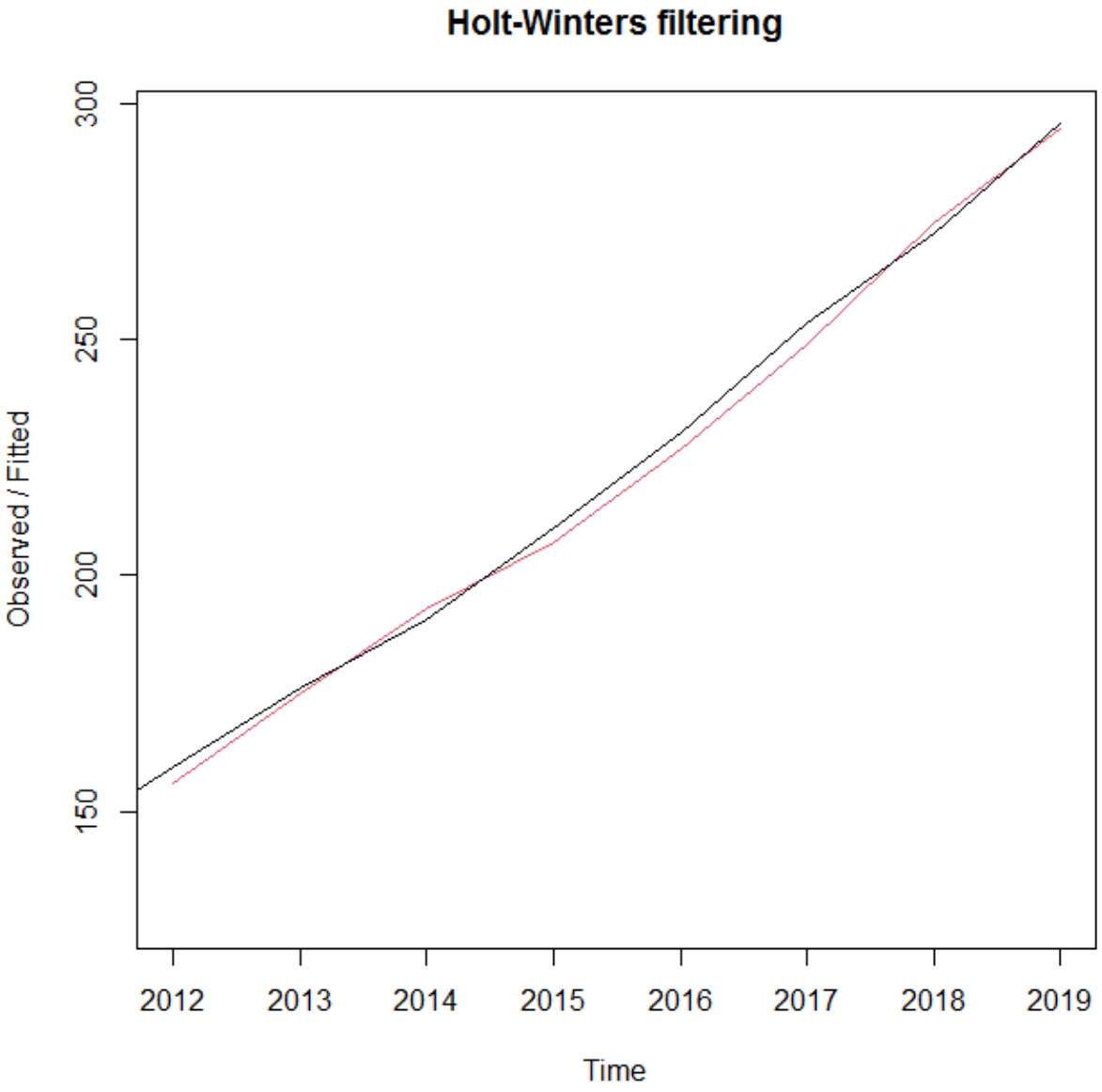

Figure 4: Comparative graph of actual and expected registered vehicles in India using the HoltWinters model

Summary of the HoltWinters model to predict registered vehicles in India:

Forecast accuracy of HoltWinters model to predict registered vehicles in India
Table - 6

ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
1.458	2.804	2.598	0.709	1.218	0.139	-0.153

Forecasted registered vehicles in India using HoltWinters model
Table - 7

Year	Forecast	LO 80	HI 80	LO 95	HI 95
2020	317.54	314.26	320.82	312.52	322.56
2021	339.66	334.07	345.25	331.11	348.21
2022	361.79	353.00	370.57	348.35	375.23
2023	383.91	371.31	396.51	364.64	403.18
2024	406.03	389.12	422.95	380.16	431.90
2025	428.15	406.49	449.82	395.02	461.29
2026	450.28	423.47	477.08	409.28	491.27
2027	472.40	440.09	504.71	422.98	521.82
2028	494.52	456.37	532.68	436.17	552.88
2029	516.65	472.33	560.96	448.87	584.42
2030	538.77	487.99	589.55	461.10	616.43

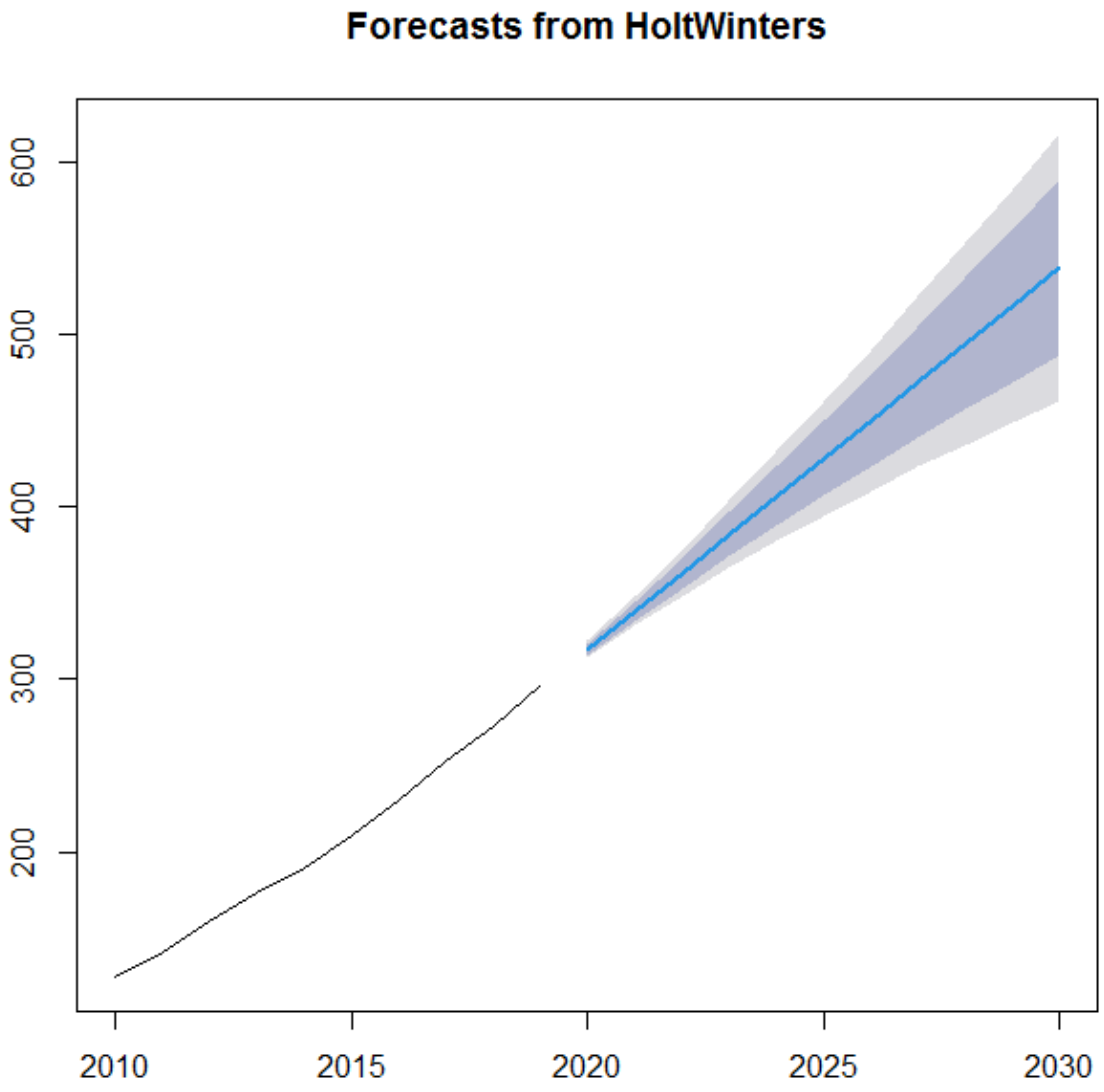

Figure 5: Forecast analysis of registered vehicles in India using the HoltWinters model for 2020 to 2030

Prediction of registered vehicles in India using the ARIMA model:

In this section, the ARIMA model is developed to predict registered vehicles in India using R software.

Summary of the ARIMA model to predict registered vehicles in India:

Forecast accuracy of ARIMA model to predict registered vehicles in India
Table - 8

ME	RMSE	MAE	MPE	MAPE	MASE	ACF1
0.898	2.850	2.320	0.420	1.054	0.124	-0.542

Forecasted registered vehicles in India using the ARIMA model
Table - 9

Year	Forecast	LO 80	HI 80	LO 95	HI 95
2020	318.96	314.87	323.04	312.71	325.20
2021	342.14	333.01	351.27	328.18	356.11
2022	365.33	350.05	380.61	341.96	388.70
2023	388.51	366.14	410.88	354.30	422.72
2024	411.70	381.41	441.98	365.38	458.02
2025	434.88	395.92	473.84	375.30	494.46
2026	458.07	409.75	506.39	384.17	531.97
2027	481.25	422.92	539.58	392.04	570.46
2028	504.44	435.49	573.38	399.00	609.88
2029	527.62	447.49	607.75	405.07	650.17
2030	550.81	458.94	642.67	410.31	691.30

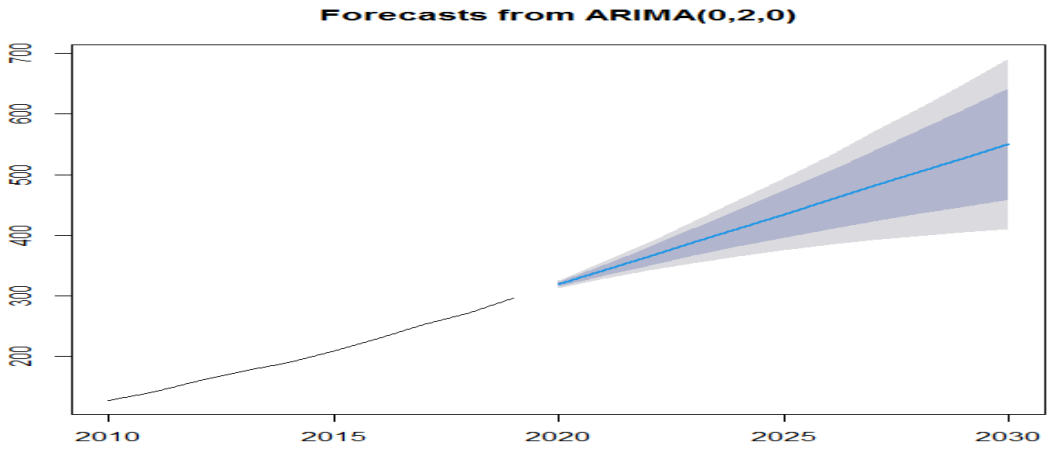

Figure 6: Forecast analysis of registered vehicles in India using the ARIMA model for 2020 to 2030

Regression analysis of deaths due to air pollution in India:

In this section regression model will be developed to predict deaths due to air pollution considering the dependence on crude oil consumption and registered vehicles in India.

Summary of regression model using R-software:
Call:
lm(formula = deaths ~ ., data = airpollutiondeaths)

Residuals:

Min	1Q	Median	3Q	Max
-29953	-11846	1756	14940	19520

Coefficients:				
	Estimate	Std. Error	t value	Pr(>|t|)
Intercept	1738454.2	146184.1	11.892	6.76e-06 ***
crude	-207282.9	80083.0	-2.588	0.03603 *
vehicle	3414.5	923.7	3.696	0 .00769 **

Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 19600 on 7 degrees of freedom
Multiple R-squared: 0.9265, Adjusted R-squared: 0.9056
F-statistic: 44.15 on 2 and 7 DF, p-value: 0.0001074

From the above summary of the regression model we can see that multiple R squared and adjusted R Squared are more than 0.9 also p-value is less than 0.05, so the model will be significant and the regression equation will be

Deaths=1738454.2- 207282.9*crude+3414.5*vehicle

Predicted deaths due to air pollution in India using the regression model
Table - 10

Year	crude	vehicle	deaths	pred_deaths
2010	3.308	127.746	1459000	1488951
2011	3.475	141.866	1498000	1502548
2012	3.674	159.491	1541000	1521479
2013	3.717	176.044	1585000	1569086
2014	3.832	190.704	1592000	1595305
2015	4.147	210.023	1608000	1595976
2016	4.544	230.031	1600000	1582002
2017	4.724	253.311	1604000	1624180
2018	4.974	272.587	1645000	1638177
2019	5.148	295.772	1667000	1681275

Accuracy of the regression model

Table - 11

Year	deaths	pred_deaths	Abs_error	MAPE
2010	1459000	1488951	29951	2.05
2011	1498000	1502548	4548	1.18
2012	1541000	1521479	19521	1.21
2013	1585000	1569086	15914	1.16
2014	1592000	1595305	3305	0.97
2015	1608000	1595976	12024	0.93
2016	1600000	1582002	17998	0.96
2017	1604000	1624180	20180	1.00
2018	1645000	1638177	6823	0.93
2019	1667000	1681275	14275	0.92
		MAD	14453.9	

Results and discussion:
In this work, initially, crude oil consumption and registered vehicles in India are predicted using HoltWinters and ARIMA models. Results of the HoltWInterss model for crude oil consumption are summarized in Table 2 and Table 3. From Table 2 we can see that the Mean Absolute Percentage Error of the HoltWinters model is 1.987, which will be considered good forecast accuracy. So according to HoltWinters model crude oil consumption of India will be 7.137

million barrels per day in 2030. Results of the ARIMA model to predict crude oil consumption of India are summarized in Table 4 and Table 5. From Table 4 we can see that the Mean Absolute Percentage Error of the ARIMA model is 1.693, which will be considered a good forecast accuracy. So according to the ARIMA model in 2030 crude oil consumption of India will be 7.397 million barrels per day. Since the forecast accuracy of the ARIMA model is better than the HoltWinters model so crude oil consumption of India is considered 7.397 million barrels per day for 2030.

Results of the HoltWinters prediction model for registered vehicles are summarized in Table 6 and Table 7. From Table 6 we can see that the Mean Absolute Percentage Error of the HoltWinters model is 1.218, which will be considered a good forecast accuracy. So according to HoltWinters model registered vehicles in India in 2030 will be 538.77 million. The results of the ARIMA model to predict registered vehicles in India are summarized in Table 8 and Table 9. From Table 8 we can see that the Mean Absolute Percentage Error of the ARIMA model is 1.05, which will be considered a good forecast accuracy. So according to the ARIMA model in 2030, registered vehicles will be 550.81 million. Since the forecast accuracy of the ARIMA model is better than the HoltWinters model so registered vehicles in India are considered 550.81 million for 2030.

Since a high correlation between deaths due to air pollution with crude oil consumption and vehicles was found, the regression model is developed to predict deaths due to air pollution considering dependent on crude oil consumption and registered vehicles in India.

From the summary of the regression model, we can see see the significant impact of crude oil consumption and registered vehicles on deaths due to air pollution.

Since the MAPE of the model is 0.92 which is close to zero, the regression model can be considered to predict deaths due to air pollution considering dependent on crude oil consumption and registered vehicles. Since the predicted value of crude oil consumption and registered vehicles in India for 2030 are 7.3968 and 550.8 respectively so deaths due to air pollution can be predicted by putting these values in equation Deaths=1738454.2-207282.9*crude+3414.5*vehicle, so predicted deaths due to air pollution for 2030 will be 2085938.

Conclusion:

In this work, historical data is analyzed to find the deaths due to air pollution due to crude oil consumption in India. A correlation analysis shows a high correlation between casualties due to air pollution and crude oil consumption and deaths due to air pollution. A regression model is developed to predict casualties due to air pollution where deaths are considered dependent on

crude oil consumption and registered vehicles in India. To find the expected crude oil consumption and registered vehicles in India for the 2030 forecast models are developed.

Using the ARIMA model predicted values for crude oil consumption in India for 2030 are found 7.39 million barrels per day. Using the ARIMA model predicted values for registered vehicles in India for 2030 are found 550.8 million. These values are used for the prediction of casualties due to air pollution using the regression model. So expected deaths due to air pollution are found 2085938 for 2030. The Indian government, regulatory bodies, and the people of India should find alternate energy sources for the transportation sector to control air pollution due to fossil fuels.

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Conflict of interest The authors declare that there is no conflict of interest

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Ethical considerations

The authors declare that all ethical issues have been taken care of.

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