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Environmental Impact Assessment of Road Traffic in Taiz City.

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Abstract
In this study an attempt was made to estimate and predict the pollution emission by road traffic in Taiz city (Yemen). Mobile 6.2 software designed by EPA in the united states was used for the estimation of the pollutions such as CO, THC, NO_x , SO_2 and PM. Hourly classified vehicle count was carried out in the city network in year 2010, and forecasted for the year 2014, 2020 and 2025. The metrological data, vehicle fleet characteristics and fuel specifications of Taiz city were fed in the software. The pollution emission for the year 2014, 2020 and 2025 were obtained. Different scenarios such as clean air act and traffic management plan in the city were investigated in order to reduce the pollution emissions.
Keywords: Traffic Air Pollution, Urban traffic Pollution, Mobile 6.

I. Introduction

Taiz is one of the 22 governorates of Yemen. It extends over 14,194 sq.km and accounts for 2.69 % of Yemen's geographical area and contained a population of 2,805,000 (2010) accounting for 12.1 % of the country's population. Taiz governorate has the biggest population size among all the governorates. The urban share is 22.8%.

Taiz city is the capital of Taiz governorate. It is a historical city of long vintage and hosts a number of heritage monuments and buildings attracting a large number of tourists. The city is built along hilly terrain of steep slopes and provides a great example of human ingenuity in city building. Located in the interior highlands at altitudes ranging between 1,100 m and 1,600 m above sea level. Its center became jammed due to its traditional narrow streets and the lack of proper traffic and parking management system. Figure (1) shows the map of the Republic of Yemen, while figure (2) shows Taiz metropolitan Region and figure (3) shows the Taiz city road network.

Figure (1): Republic of Yemen.

Figure (2): Taiz Metropolitan Region.

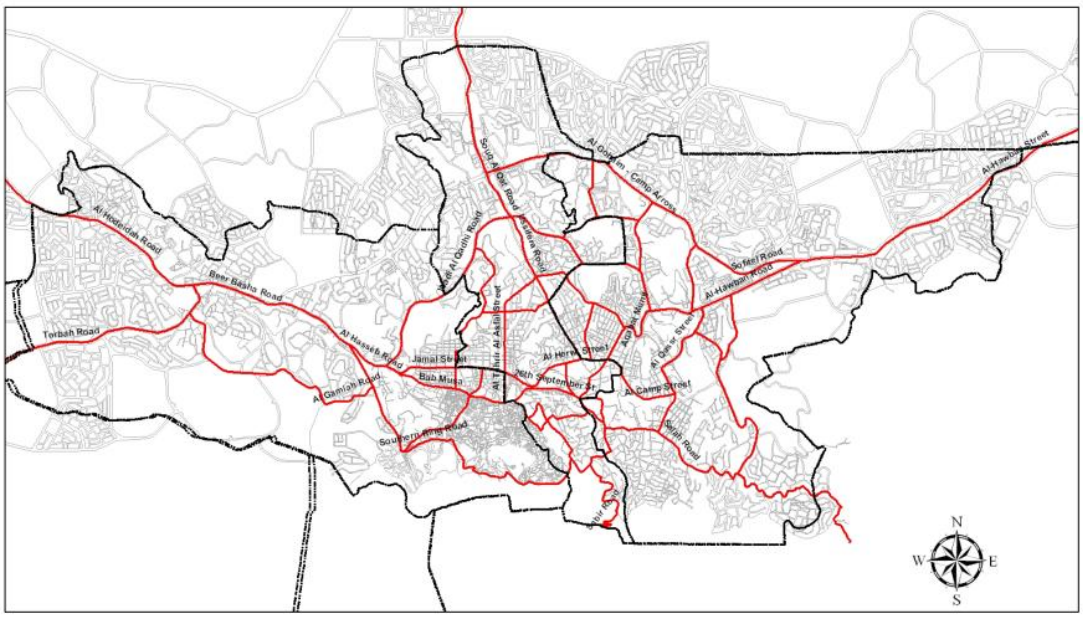


Figure (3): Taiz city Road Network.

II. Environmental Characteristics

Due to the absence of heavy industries in Taiz, and coupled with heavy rainfall and mountainous terrain resulting high wind speeds. The traffic is major source of pollution in the city, deterioration of environment might occur due to rapid increase in private vehicles

III. Increase in Registered Vehicles

The registered vehicles in Taiz have grown at a rapid average annual growth rate of 16.5% since 1996 and are expected to grow at the same rate. Cheap availability of old vehicles from developed countries also has resulted in increase in the vehicle numbers. The influence of development of neighboring countries and some possible oil exploration in future may cause a rapid surge in Yemen economy, which will increase vehicle on roads. If necessary steps are not taken in terms of curbing the private vehicles, in future further environmental deterioration may happen. Figure (2) shows the growth of vehicles in Taiz.

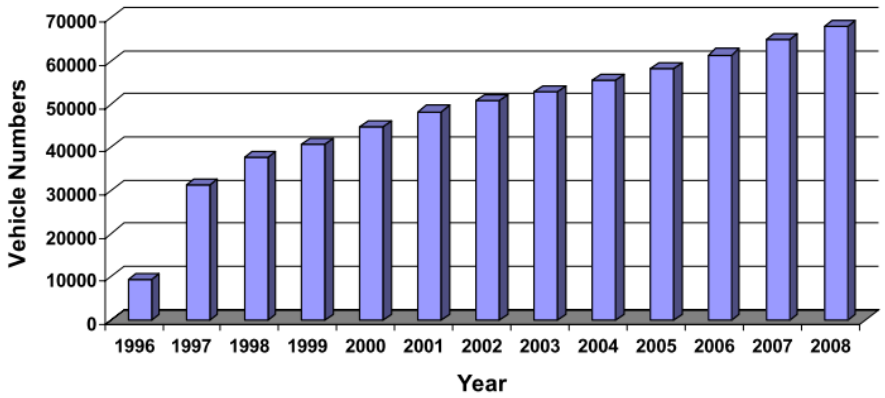


Figure (4): Growth of vehicles in Taiz.

IV. Vehicle Technology

Predominant share of vehicles on roads are of modern technology. However, two wheelers, taxis and commercial vehicles are still based on old technology. Two wheelers in particular have conventional two stroke engine and are a major cause of vehicular air pollution and effect is enhanced due to presence of hilly terrain.

The prime mode of public transport in Taiz for intra city travel is medium size buses and vans popularly known as Dhabbabs having seating capacity of 9, 13 and 26. 13 seater Dhabbas are more in number as compared to others. These vehicles Dhabbabs are old diesel based vehicles with high fuel consumption. The composition of Dhabbabs is maximum (30%) in traffic and perform maximum trips in a day by any mode. Diesel as fuel with high sulphur content and low propulsion on hilly terrains cause increase in exhausts which intern cause increase in air pollution.

V. Age of Vehicles

Predominant share of vehicles on roads are of modern technology. However, two wheelers, taxis and commercial vehicles are still based on old technology. Two wheelers in particular have conventional two stroke engine and are a major cause of vehicular air pollution and effect is enhanced due to presence of hilly terrain.

44% of Dhabbabs were in age band of 10-15 years and 48% are above 15 years of age. This particular share of vehicles has been over utilized in terms of life span. Similarly other vehicles like Peugeot taxis and other intra city taxis constitute more 17% of traffic and have a very high trip rate. These all vehicles are very old and run on conventional technology and are major source of air pollution. There is a need to introduce new technology based on alternative fuels for public transport and restricting the use of over aged vehicles particularly in urban areas.

VI. Air Quality model

In this study Mobile6 model used to estimate and predict the emission from vehicles movement in Taiz city. MOBILE6 was designed by the U.S. Environmental Protection Agency (EPA) to address a wide variety of air pollution modeling needs. Written in Fortran and compiled for use in the desktop computer environment, the model calculates emission rates under various conditions affecting in-use emission levels (e.g., ambient temperatures, average traffic speeds) as specified by the modeler. MOBILE models have been used by EPA to evaluate highway mobile source control strategies; by states and local and regional planning agencies to develop emission inventories and control strategies for State Implementation Plans under the Clean Air Act; by

metropolitan planning organizations and state transportation departments for transportation planning and conformity analysis; by academic and industry investigators conducting research; and in developing environmental impact statements.

The model predicts emissions of hydro carbons, carbon mono oxide, oxides of nitrogen, particulate matter and sulfur dioxide in gram per vehicle-mile for different types of vehicles. Vehicles types include light duty gasoline-powered vehicles, light duty gasoline-powered trucks, heavy-duty gasoline-powered trucks, light-duty diesel -powered vehicles, heavy-duty diesel-powered vehicles, and motorcycles.

The mathematical form of the models is basic emissions factor multiplied by a set of correction factors related to environmental and operating characteristics. Correction factors account for variations in ambient temperature, fuel volatility level, air conditioner use, loading and trailer towing, and vehicular operating mode, speed, age, and mileage accumulation. Total daily or annual emissions may be predicted by multiplying the corrected emissions factors by the total vehicle-miles of travel for particular vehicle types and then summing over all vehicle types.

Basic emissions rates and correction factors are determined from the Federal Test Procedure (FTP).

The model assumes that vehicles from the previous 20 model years are operating during any given year. They contain build-in estimates of he mileage accumulation of each model year and the distribution of model years in the fleet in any given year. Emissions factors are assumed to increase with age because of mechanical deterioration with increase mileage. It is also assumed that for any given calendar year, vehicle of any particular model year accrue mileage, operate, and are subject to environmental conditions similar to all other vehicles of that model year; consequently, the model are not sensitive to the composition of the fleet in terms of make of vehicles.

VII. Modeling Traffic Air Pollution in Taiz City

Mobile6 software was used to estimate and predict air pollution in Taiz city. In order Mobile6 predict correctly the emission rate by traffic, the following input parameters have been modified in the software:

a) Metrological data:
   Min/Max Temperature
   Absolute Humidity
Altitude

b) Vehicle Fleet Characteristics:
   Vehicle Mile Traveled Fractions
   Distribution of Vehicle Registration (Age)
   Average Speed
   Diesel Fractions

c) Fuel Specifications:
   Gasoline Sulfur Content
   Diesel Sulfur Content
   Fuel Reid Vapor Pressure (RVP)

VIII. Scenarios for Modeling Traffic Air Pollution

The Yemeni ambient air quality norms are similar to that of adopted by United States, however, the apart from ambient air quality standards United States has adopted other measures like emission norms for vehicles to curb pollution.

The Yemeni warrants for air quality no where mentions the vehicle emission norms for different modes. The norms for vehicle emission can play a very important role in curbing vehicular pollution as these norms are considered while manufacturing vehicles. This warrants can make technology change in vehicles and there by reducing pollution.

Yemeni Environment protection legislation requires amendment to include emission norms for all vehicles and periodic pollution checks e.g. 1990 Clean Air Act amendments, Tier1, Tier2 etc... Standards adopted by the United States EPA or EURO 1-4 standards adopted by European Union.

Two scenarios were considered for modeling traffic air pollution in Taiz city, viz. do nothing scenario and alternative scenarios.

Do Nothing Scenario:

At present there are no laws or regulations in Taiz city which prevent vehicle owners to control the vehicular emission rate. Moreover, as mentioned earlier, considerable amount of vehicles have old technology and are in the age band of 10-15 years, and many of the imported vehicles are used (old) vehicles from developed countries. In addition, the fuel used in the city has high percentage of sulfur (gasoline 0.1% and diesel 0.348% by mass).

To model the above mentioned short coming in transportation system in Taiz city, we have to disable the 1990 Clean Air Act Amendments requirements (CAA) in Mobile6.

Vehicular emission in Taiz city for the years 2014, 2020 and 2025 were modeled using do nothing scenario. Table (1) shows area wise daily emission in tons of Total Hydro Carbon, Carbon mono oxides, Nitrogen oxides, Particulate matter and Sulfur dioxides in Taiz in different years (do nothing scenario).

Table (1): Area wise daily emission of pollutants in tons in different years, (do nothing) scenario.

Year	Pollutants	Area			
		Central (CBD)	Mid (suburb)	Outer Cordon	Total
2014	THC	3.998	2.600	9.673	16.271
	CO	30.698	19.942	69.172	119.811
	NO_x	3.519	2.513	15.010	21.042
	PM	0.141	0.095	0.538	0.774
	SO_2	1.074	0.725	4.058	5.857
2020	THC	4.841	3.148	11.712	19.701
	CO	37.169	24.145	83.754	145.069
	NO_x	4.261	3.043	18.174	25.478
	PM	0.170	0.115	0.651	0.937
	SO_2	1.300	0.878	4.913	7.091
2025	THC	5.695	3.702	13.776	23.173
	CO	43.721	28.401	98.516	170.638
	NO_x	5.012	3.580	21.377	29.969
	PM	0.200	0.136	0.766	1.102
	SO_2	1.530	1.033	5.779	8.341

It is clear from Table (1) that the daily emission of Total Hydro Carbon is 16.271 ton, 119.811 tons of Carbon mono oxides, 21.042 tons of Nitrogen oxides, 0.774 ton of Particulate matter and 5.857 tons of Sulfur dioxides in Taiz on a typical summer day in year 2014. Figure (5) shows the daily emission in tons of Total Hydro Carbon, Carbon mono oxides, Nitrogen oxides, Particulate matter and Sulfur dioxides in the central area for the years 2014, 2020 and 2025.

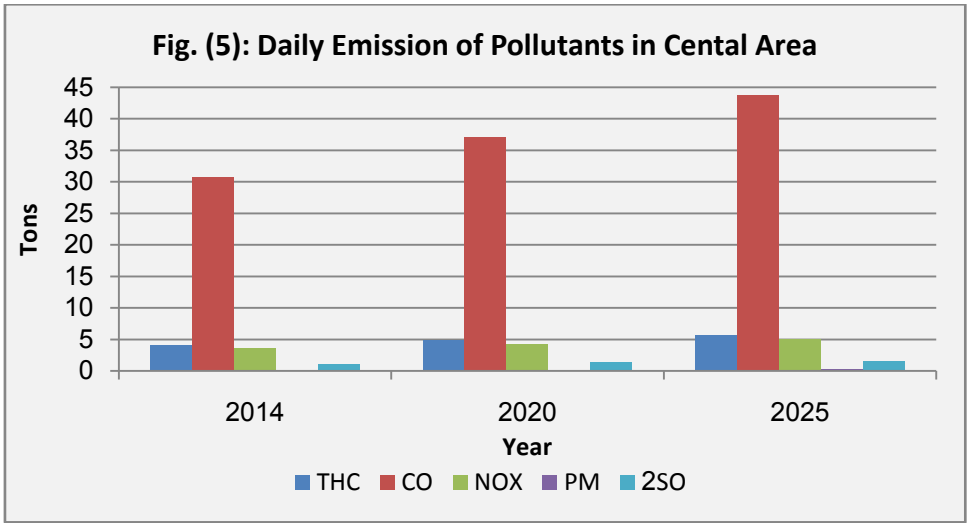


Figure (6) shows the daily emission in tons of Total Hydro Carbon, Carbon mono oxides, Nitrogen oxides, Particulate matter and Sulfur dioxides in the mid area for the years 2014, 2020 and 2025.

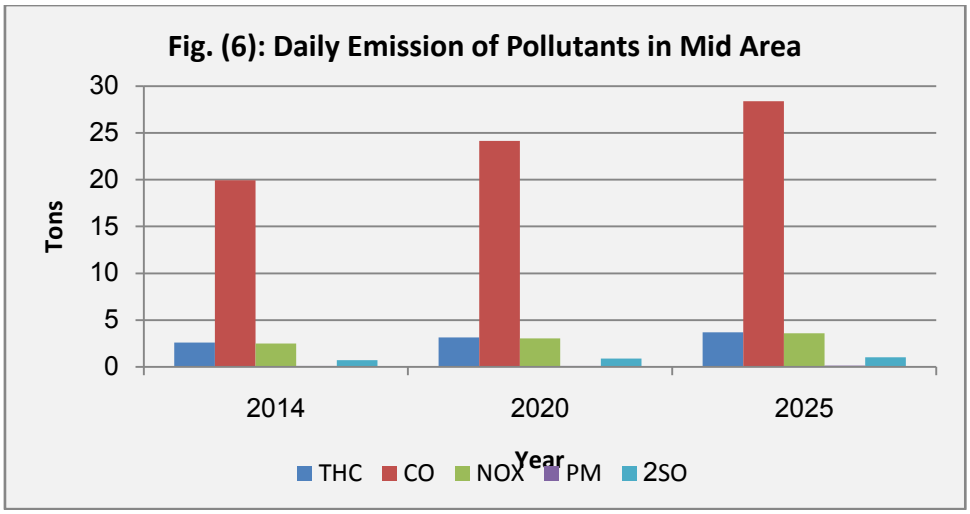


Figure (7) shows the daily emission in tons of Total Hydro Carbon, Carbon mono oxides, Nitrogen oxides, Particulate matter and Sulfur dioxides in the outer area for the years 2014, 2020 and 2025.

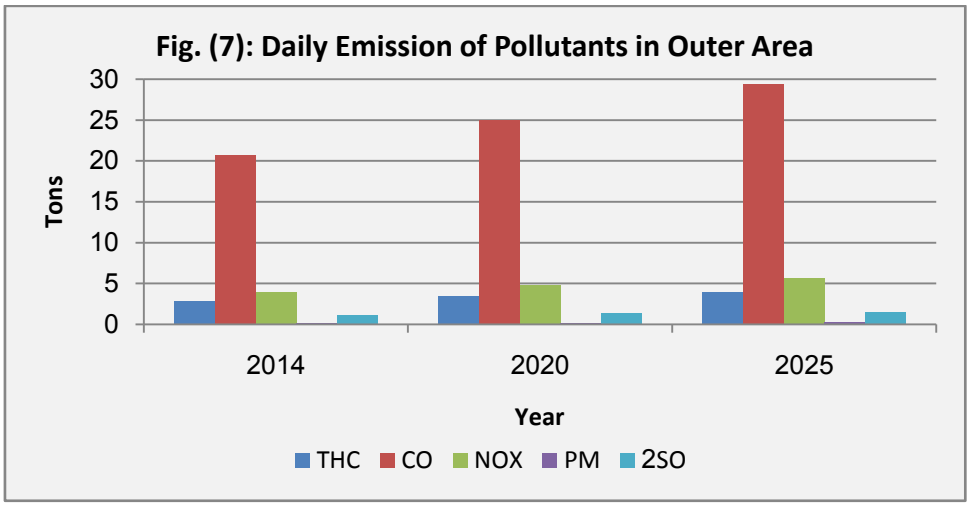
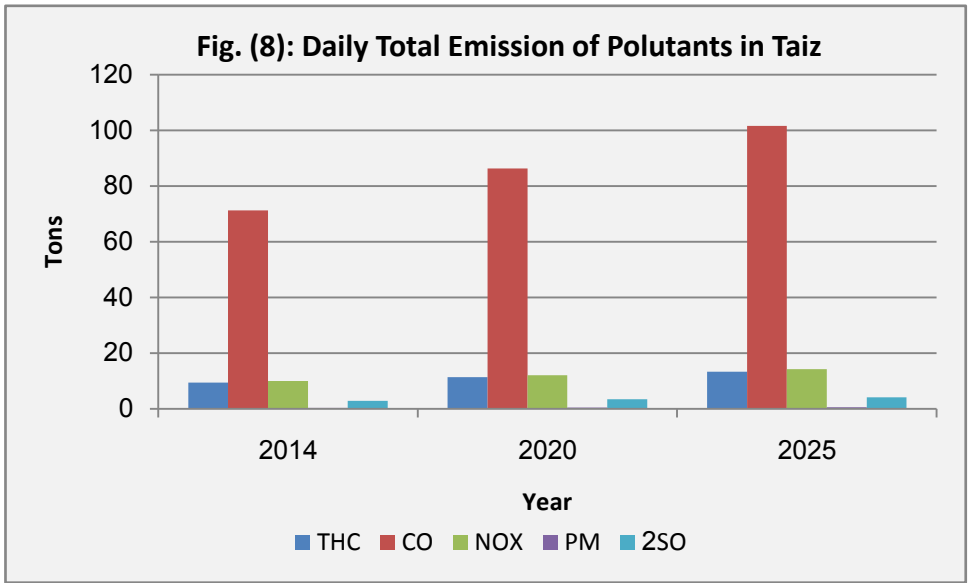


Figure (8) shows the daily emission of different traffic pollutants in whole Taiz for the years 2014, 2020and 2025.

These comparatively low values of traffic emissions of various pollutants in Taiz city as shown in Table (1), especially in central area coupled with heavy rainfall and mountainous terrain resulting high wind speeds which will lead to quick dispersion of the above mentioned pollutants.



IX. Dispersion of Air Pollutants:

Pollutants emitted into the atmosphere are mixed thoroughly with the surrounding air and diluted by atmospheric dispersion. This dispersion is primarily due to turbulent diffusion and bulk air flow. In this study the Gaussian plume model was used to predict the concentration of pollutants downwind of a line source situated at ground level.

For infinite line source such as heavy traffic along a long stretch of road, the ground-level downwind concentration of pollutants is given by:

$$(\rho_A)\,(x,y,0,0) = \frac{2q}{(\sqrt{2\pi})^* \sigma_z u} \longrightarrow \quad (1)$$

Where,
q= Q/l = source strength per unit distance (gram/ m. sec)
u = wind speed m/sec
σ z = dispersion coefficient

The above equation was used to predict the dispersion of traffic pollutants in the atmosphere and to find out the concentration of pollutant in the atmosphere in micro gram per cubic meter.

The analysis revealed that the concentration of pollutants in the atmosphere due to traffic movement Taiz city for the base year as well as future years till 2025 will not exceeded the Yemeni ambient air standards provided that there will be no other sources of pollution such as heavy industries etc..

However, it is advisable to think about adopting higher emission norms such as 1990 clean air act of the united states or European emission standards Euro I, because in country like Yemen, adopting new norms, training staffs and importing necessary equipments will take years. So, if a decision taken to adopt higher norms, may be after 5 or 10 years we will be able to correctly implement that norm.

Alternative Scenarios:

1- Clean Air Act :

The first step to improve the traffic air quality emission in Taiz city for the future years will be to adopt emission norms for vehicles similar to 1990 Clean Air Act (CAA) used in the united states (or its European counter part Euro I), then higher norms may be thought about.

In this study, alternative analysis was carried out using the 1990 Clean Air Act amendment. The input to Mobile6 software was modified to take into consideration the 1990 Clean Air Act (CAA), as well as improved fuel specifications (sulfur 0.05 % by mass).

Vehicular emission for Taiz city for the years 2014 and 2020 and 2025 were modeled using alternative scenario (Clean Air Act). Table (2) shows area wise daily emission in tons of Total hydro carbon, Carbon mono oxide, Nitrogen oxides, particulate matter and Sulfur dioxides.

Table (2): Area wise daily emission of pollutants in tons in different years, (Clean Air Act) scenario.

Year	Pollutants	Area			
		Central	Mid	Outer	Total
2014	THC	2.500	1.539	5.228	9.266
	CO	20.588	12.647	38.958	72.193
	NOX	1.948	9.103	8.368	19.419
	PM	0.108	0.069	0.311	0.488
	SO2	0.026	0.018	0.086	0.130
2020	THC	3.027	1.863	6.330	11.220
	CO	24.929	15.313	47.171	87.412
	NOX	2.359	11.022	10.132	23.513
	PM	0.130	0.084	0.376	0.591
	SO2	0.031	0.022	0.105	0.158
2025	THC	3.561	2.191	7.445	13.197
	CO	29.322	18.012	55.485	102.819
	NOX	2.775	12.965	11.918	27.658
	PM	0.153	0.099	0.443	0.695
	SO2	0.037	0.025	0.123	0.186

It is clear from Table (2) that the daily emission of Total Hydro Carbon is 9.266 ton, 72.193 tons of Carbon mono oxides, 19.419 tons of Nitrogen oxides, 0.488 ton of Particulate matter and 0.130 tons of Sulfur dioxides in Taiz on a typical summer day in year 2014. Figure (9) shows the daily emission in tons of Total Hydro Carbon in Taiz for both the scenarios, it is clear that clean air act has considerable impact on reduction of THC for the years 2014, 2020 and 2025.

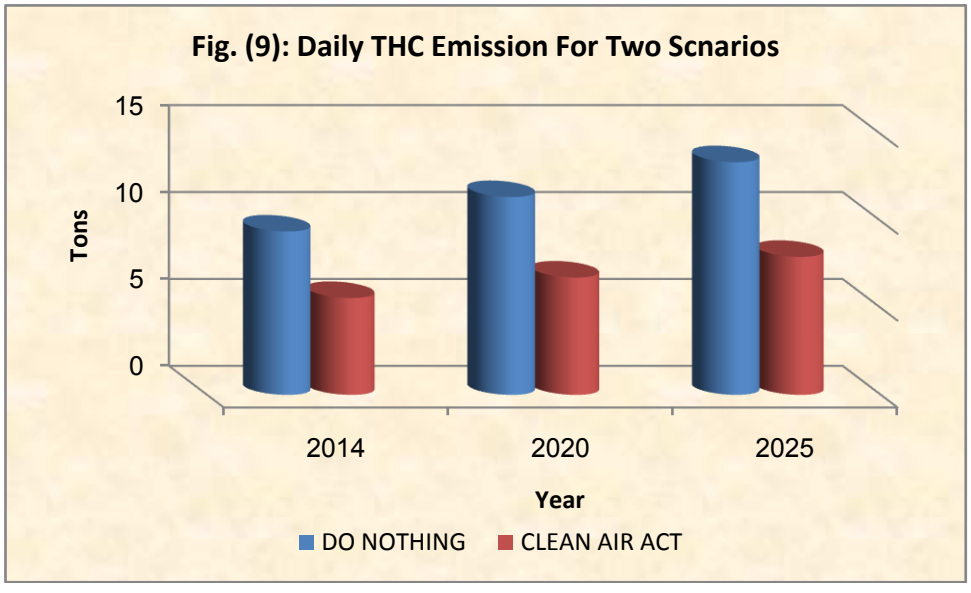


Figure (10) shows the daily emission in tons of Carbon mono oxide in Taiz for both the scenarios, it is obvious that clean air act has considerable impact on reduction of CO for the years 2014, 2020 and 2025.

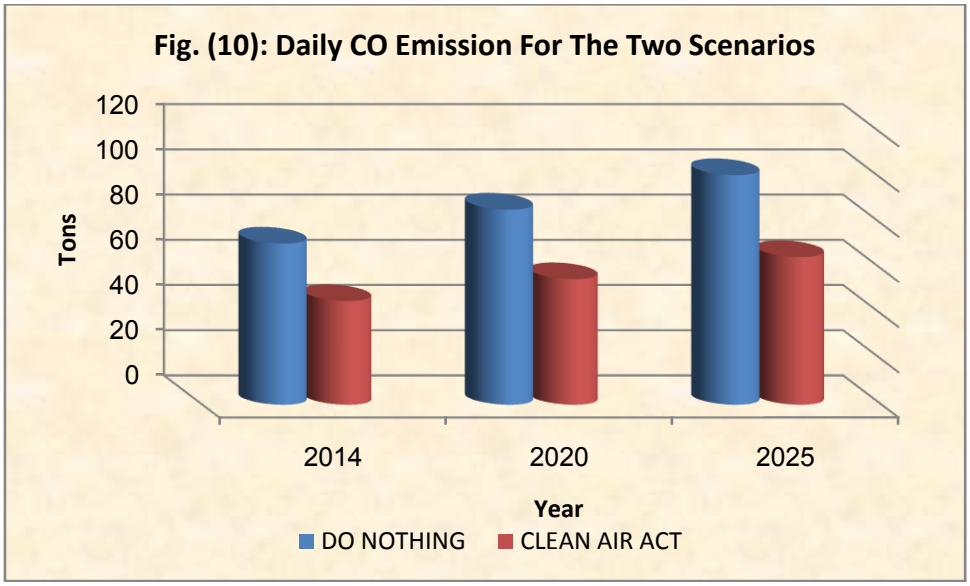


Figure (11) shows the daily emission in tons of Nitrogen oxides in Taiz for both the scenarios, it is clear that clean air act has considerable impact on reduction of NO_x for the years 2014, 2020 and 2025.

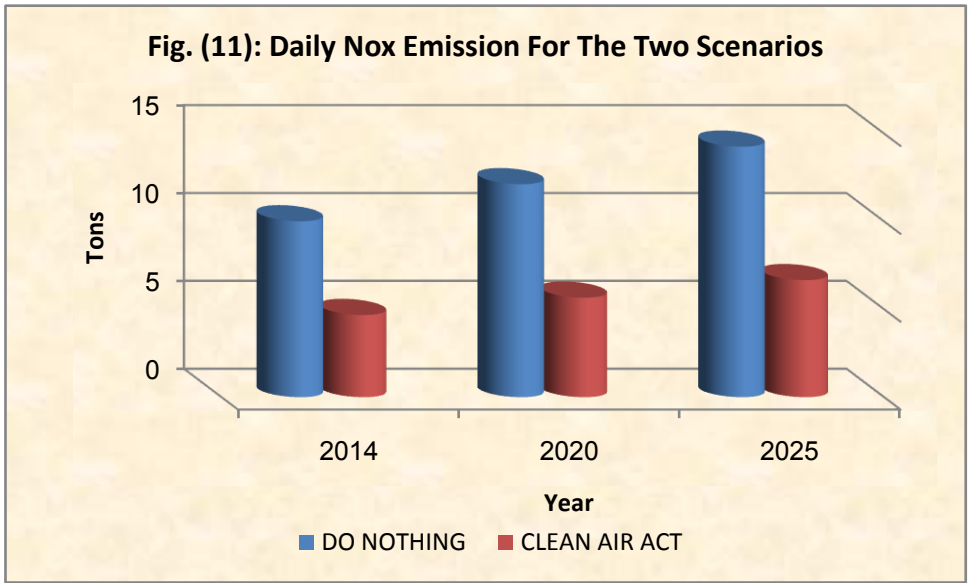


Figure (12) shows the daily emission in tons of particulate matter in Taiz for both the scenarios, it is clear that clean air act has considerable impact on reduction of PM for the years 2014, 2020 and 2025.

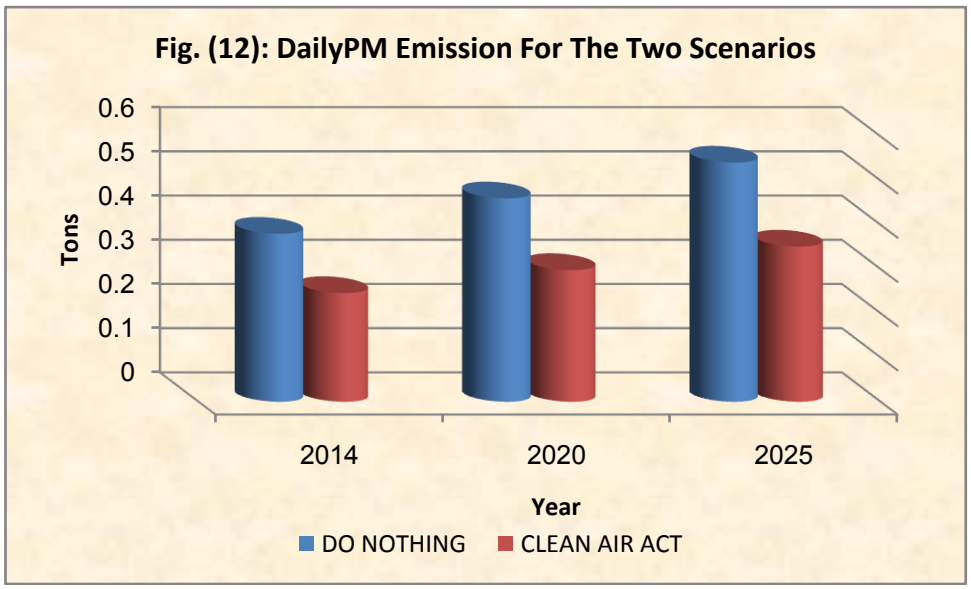
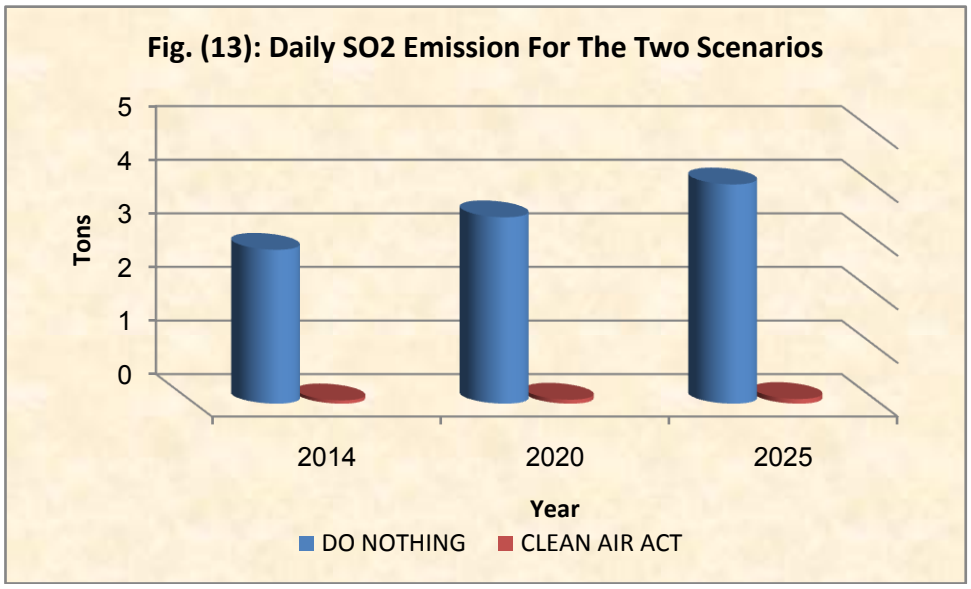


Figure (13) shows the daily emission in tons of sulfur dioxides in Taiz for both the scenarios, it is clear that clean air act has huge impact on reduction of SO_2 for the years 2014, 2020 and 2025, the main reason due to the assumption of using clean fuel with less percentage of sulfur.



2- Traffic Improvement in Central Area:

To decongest the central area of Taiz city, a traffic management plan was suggested by changing two way traffic to one way in some routes. The environmental impact of this improvement in considered in this section. The air pollution due to traffic at central area was compared for different scenarios. Four scenarios were compared viz. do nothing scenario at the central area (DN), do nothing with traffic management plan at central area (DNTMP) ,Clean Air Act (CAA) at the central area, and traffic management with clean air act (CAATMP).

Figures (14), (15), (16) , (17) and (18) show the daily emission index of total hydro carbon, carbon mono oxide, nitrogen oxides, particulate matter, and sulfur dioxide respectively for different scenarios.

It is clear from figure (14) that on any typical summer day in 2014, the THC emissions will be reduced by 21.7% if a traffic management plan (DNTMP) is adopted at the central area, in the same year the emission of THC will be reduced by 36.9% if clean air act (CAA) is implemented at the central area, similarly, the emission of THC will be reduced by 50.3% if CAA norms implemented along with traffic management plan (CAATMP) in 2014.

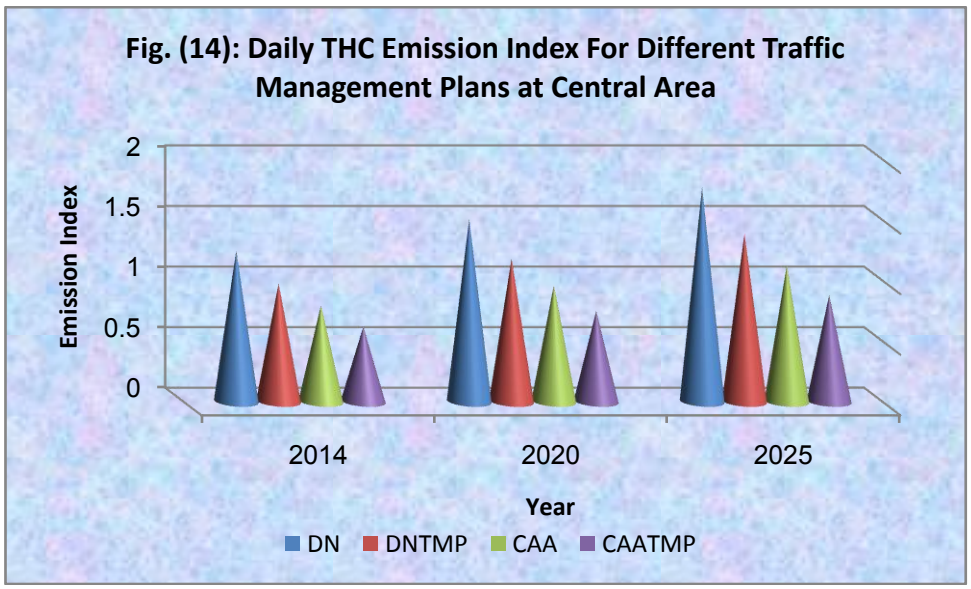


Figure (15) indicates that on any typical summer day in 2014, the CO emissions will be reduced by 22.2% if a traffic management plan (DNTMP) is adopted at the central area, in the same year the emission of CO will be reduced by 32.2% if clean air act (CAA) is implemented at the central area, similarly, the emission of CO will be reduced by 47.4% if CAA norms implemented along with traffic management plan (CAATMP) in 2014.

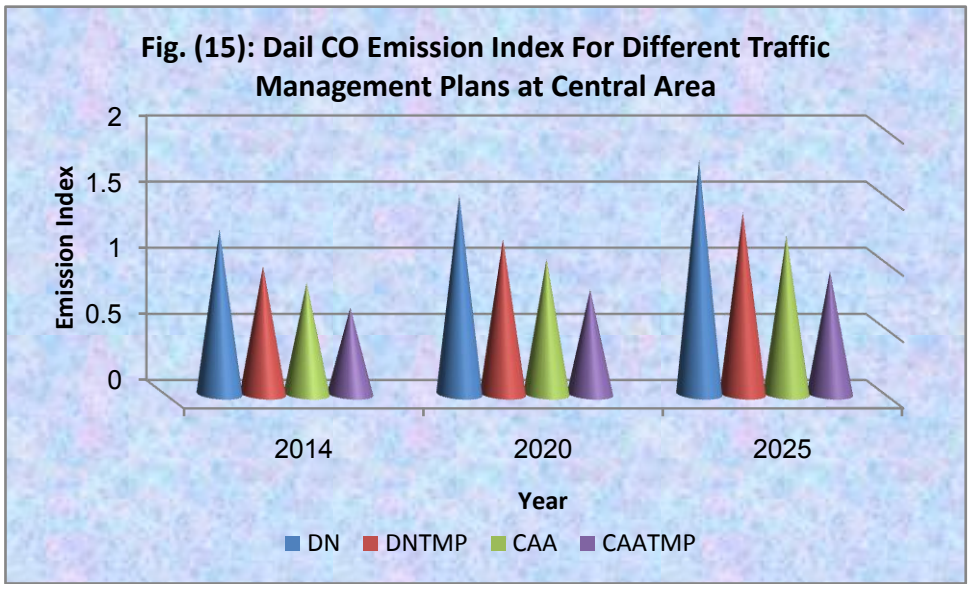
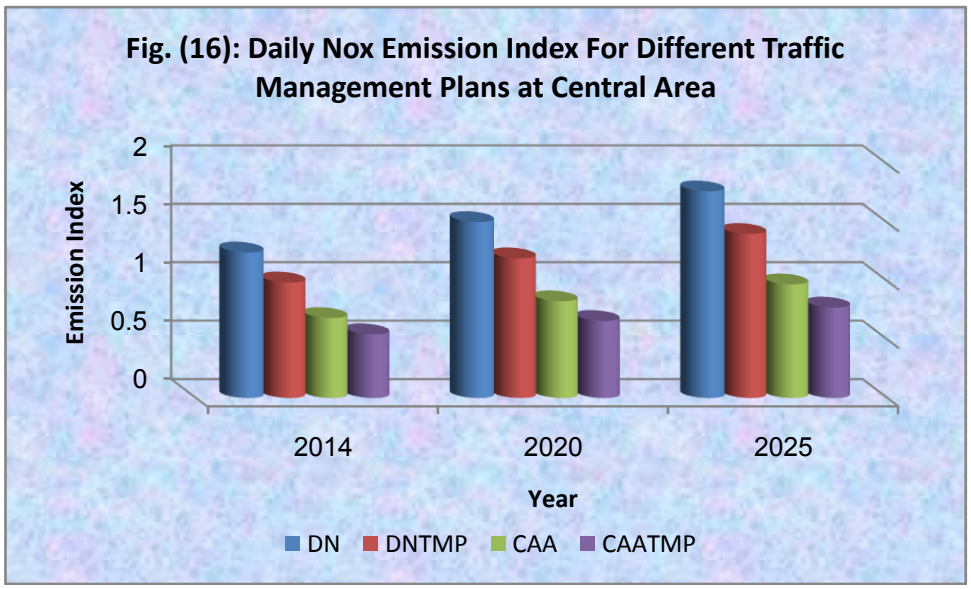


Figure (16) reveals that on any typical summer day in 2014, the NO_x emissions will be reduced by 20.6% if a traffic management plan (DNTMP) is adopted at the central area, in the same year the emission of NO_x will be reduced by 45% if clean air act (CAA) is implemented at the central area, similarly, the emission of NO_x will be reduced by 56.2% if CAA norms implemented along with traffic management plan (CAATMP) in 2014.



It is clear from figure (17) that on any typical summer day in 2014, the PM emissions will be reduced by 19.5% if a traffic management plan (DNTMP) is adopted at the central area, in the same year the emission of PM will be reduced by 23.5% if clean air act (CAA) is implemented at the central area, similarly, the emission of PM will be reduced by 38.2% if CAA norms implemented along with traffic management plan (CAATMP) in 2014.

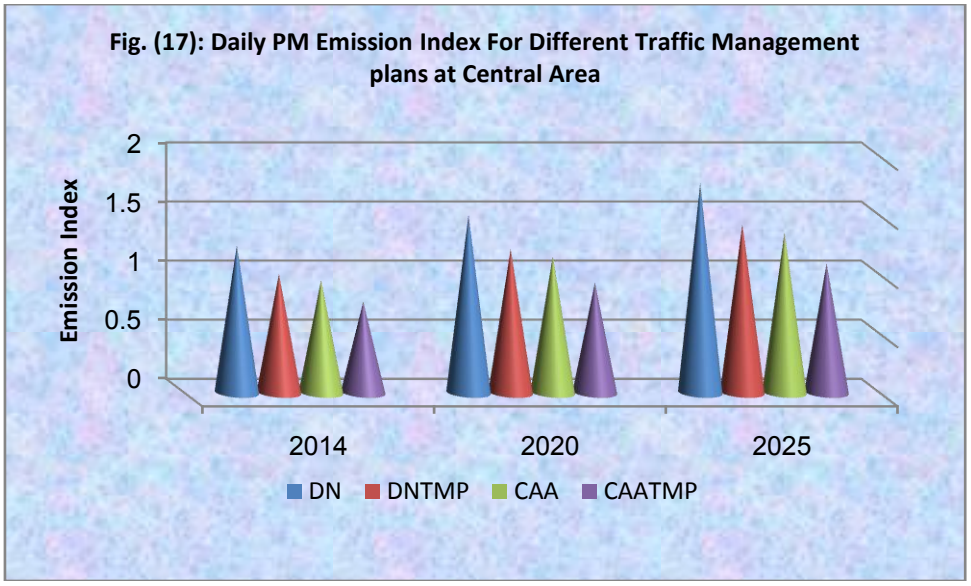
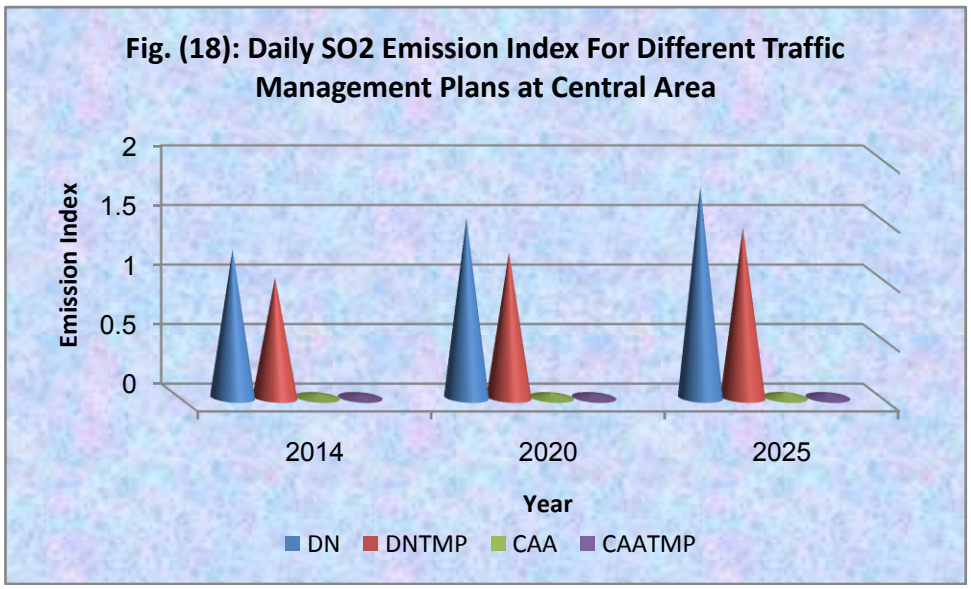


Figure (18) indicates that on any typical summer day in 2014, the SO_2 emissions will be reduced by 19.2% if a traffic management plan (DNTMP) is adopted at the central area, in the same year the emission of SO_2 will be reduced by 97.2% if clean air act (CAA) is implemented at the

central area, similarly, the emission of SO_2 will be reduced by 97.8% if CAA norms implemented along with traffic management plan (CAATMP) in 2014. It is obvious from figure (18) that using clean fuel with 0.05 percent sulfur by mass has reduced the emission of sulfur dioxide to great extend.

It is clear from figures (14), (15), (16), (17) and (18) that the traffic improvement plan in the central area has significant impact on reduction the traffic air pollution in the central area.



X. Legislation/ Warrants for Environment

Yemen has developed a number of legal instruments at various levels of government directly or indirectly concerned with environment protection. It is party to a number of international conventions, agreements and treats that have environmental implications. Table 3 presents the ambient air quality standards and their comparison with standards given by various other organizations.

Table (3): Ambient Air quality Norms

Parameter (1)	Country or Organization					
	Averaging Period	USA(1)	WHO(2)	World Bank(3)	Japan(4)	Yemen(5)
SO_2	Annual	0.06	-	1.00	0.26	0.06
	24-Hour Maximum	0.365	0.90	0.50	0.11	-
	24-Hour Average	-	-	1.00	-	0.15
	1-Hour Average	-	0.35	0.19	-	0.35
NO_2	Annual	0.10	-	0.10	-	-
	24-Hour Maximum	-	-	-	0.08	-
	24-Hour Average	-	-	0.50	-	0.15
	1-Hour Average	-	0.19-0.32	-	-	0.4
O_3	1 Hour Maximum	0.235	-	-	0.06 ppm	0.06 ppm
Particulates	Annual	0.065-0.075	0.60-0.90	0.50	-	
	24-Hour Maximum	0.15-0.26	-	-	0.20	0.07
	24-Hour Average	-	0.15-0.23	-	0.10	-
	1-Hour Average	-		-	0.20	-

Sources:

1- USA Standards are federal Standards as reported by the California Air Resources Board 9 January 2003.
2- World Health Organization- Standards as cited by various websites.
3- World Bank websites, including World Bank, Environmental Department, Initial Draft of Industrial Pollution and Abutment Handbook, January 1995.
4- Environmental Quality in Japan, Ministry of Environment, Government of Japan, current website (www.env.go.jp).
5- Implementation list of the Environmental Protection Law, Yemen, 2005.

XI. Conclusions

The following conclusions can be drawn from this Study:

- The environmental impact study for Taiz city for the years 2014, 2020 and 2025 were carried out in this study.
- The Taiz fleet generates 119.8 tons of carbon mono oxide (CO), 16.271 tons of total hydro carbon (THC), 21.042 tons of nitrogen oxides (NO_x), 0.774 ton of particulate mater (PM) and 5.872 tons of sulfur dioxide (SO_2) on a typical summer day in 2014 (do nothing scenario).
- If Taiz city adopted higher emission norms e.g. similar to the 1990 clean air act (CAA) of the united states, then daily emission of Taiz city will be reduced to 72.193 tons of (CO), 9.266 tons of (THC), 19.416 tons of (NO_x), 0.488 ton of (PM) and 0.13 ton of (SO_2) on a typical summer day in 2014.
- On any typical summer day in 2014, the CO emissions will be reduced by 22.2% if a traffic management plan (DNTMP) is adopted at the central area, in the same year the emission of CO will be reduced by 32.2% if clean air act (CAA) is implemented at the central area, similarly, the emission of CO will be reduced by 47.4% if CAA norms implemented along with traffic management plan (CAATMP) in 2014.
- Similarly, the traffic management plan at the central area has considerable effect on the reduction of daily emission of THC, NO_x, PM and SO_2.
- Alternative fuel technologies for public transport can be introduced in order to reduce the emissions. Yemen having rich petroleum resources, following fuels may be considered for public transport.
    - Standard diesel
    - Ultra Low Sulfur Diesel (ULSD)
    - Bio-diesel (mix of bio-mass like oil from Jatropha plants with diesel)
    - Natural gas (compressed or liquefied)
    - Liquefied Petroleum Gas (LPG)
    - Di-methyl Ether (DME)
- Yemeni Environment protection legislation requires amendment to include emission norms for all vehicles and periodic pollution checks e.g. United States clean air act, Tier 1, Tier 2 etc... Or EURO 1-4 standards adopted by EU.

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