A

Major Project Report

on

ESTIMATION OF VEHICULAR EMISSION LOAD ALONG A SELECTED ROAD CORRIDOR IN DELHI

submitted in partial fulfillment of the requirements for the award of degree of

Master of Technology

in

Environmental Engineering

by

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CANDIDATE'S DECLARATION

I, Sanjeev Singh Sepavat, Roll No.2K22/ENE/04 of M.Tech Environmental Engineering, hereby declare that the project Dissertation titled **"Estimation of Vehicular Emission Load Along a Selected Road Corridor in Delhi"** which is submitted by me to the Department of Environmental Engineering, Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the degree of Master of Technology in Environmental Engineering is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of my Degree, Diploma Associateship, Fellowship, or other similar title or recognition.

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CERTIFICATE BY THE SUPERVISORS

I, hereby certify that the project Dissertation titled "ESTIMATION OF VEHICULAR EMISSION LOAD ALONG A SELECTED ROAD CORRIDOR IN DELHI" which is submitted by Sanjeev Singh Sepavat, Roll No. 2K22/ENE/04 (Department of Environmental Engineering), Delhi Technological University, Delhi in partial fulfillment of the requirement for the award of the Degree of Master of Technology is a record of the project carried out by the student under my supervision.

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SUMMARY

Globally, vehicular emissions are recognized as the main source of air pollution in urban areas. The trend of urbanization has led to a surge in private vehicle ownership, particularly in metropolitan cities such as Delhi, India, resulting in significant growth of the automobile sector. Additionally, Delhi has experienced a considerable influx of people migrating from neighboring states in the past decade, leading to higher demand for transportation facilities. The growing number of vehicles has a direct impact on air pollution by causing higher fuel consumption and increased traffic congestion. The activity of vehicles on congested roads, including sudden acceleration and deceleration, significantly affects emissions. As a result, precise estimation of vehicular emissions is critical in developing systematic pollution mitigation strategies.

This study focuses on the estimation of vehicular emission loads along a selected road corridor in Delhi, aiming to evaluate the effectiveness of various mitigation policies. Utilizing the CPCB VKT method, the emissions of key pollutants including Carbon Monoxide (CO), Hydrocarbons (HC), Particulate Matter (PM), Nitrogen Oxides (NOx), and Carbon Dioxide (CO_2) were measured. Multiple scenarios were developed to analyze the impact of different policies, and these were compared with the Business-As-Usual (BAU) scenario to determine their effectiveness. The results provide valuable insights into the potential benefits of implementing specific strategies to reduce vehicular emissions and improve air quality in urban settings. Scenario 1,2 and 3 reduces the vehicular pollution significantly. So, we can say that adopting electric vehicle will help to curb vehicular pollution more efficiently.

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LIST OF ABBREVIATION

CRRI - Central Road Research Institute

CPCB - Central Pollution Control Board

VKT - Vehicle Kilometers Traveled

BAU - Business-As-Usual

CO - Carbon Monoxide

HC - Hydrocarbons

PM - Particulate Matter

NOx - Nitrogen Oxides

CO_2 - Carbon Dioxide

MORTH - Ministry of Road Transport and Highways

CHAPTER 1

INTRODUCTION

1.1 Background

Air pollution leads to 7 million deaths prematurely every year the intricate connection between air pollution and climate change is emphasized, with major pollutants impacting the climate and sharing common sources with greenhouse gases. The urgent need to enhance air quality is underscored by the fact that in 2019, 99% of the world's population lived in places where the WHO's strictest 2021 air quality guidelines could not meet. Despite being a global issue, air pollution disproportionately affects individuals in developing nations, particularly vulnerable populations such as women, children, and the elderly. Residential pollution, coming out from biomass-based cooking, heating, electricity generation from fossil fuels, and transportation, remains a primary source of global fine particles. Additionally, windblown dust contributes significantly in regions close to deserts in Africa and West Asia. In 2019, approximately four million people died due to the effects of fine particulate matter outdoor air pollution, with the highest death rates were in East Asia and Central Europe. This exposure to outdoor air pollution stands as the foremost environmental risk factor for premature death globally, contributing to various key illnesses, albeit unequally distributed across the world. [1] [2]

Impact of air pollution on public health and economic well-being in India has been a matter of increasing concern, as evidenced by various studies. The Global Burden of Disease Study in 2017 conducted a state-wise analysis in India, revealing significant impacts on deaths, disease burden, and life expectancy due to air pollution [3]. According to [4], the air pollution levels in Indian cities, on average, surpassed the World Health Organization's (WHO) recommended safe limit threshold by a staggering 500%. The World Air Quality report of 2020 identified 22 out of the 30 most polluted cities globally as being located in India [30]. Furthermore, WHO's assessment in 2019 India was the fifth most air-polluted country in the world based on PM2.5 concentrations. The grim consequences of this air pollution crisis are underscored by [5] who estimated that about 1.7 million deaths in 2019 in India were attributed to the direct and indirect effects of air pollution, constituting approximately 18% of total deaths during that period.

Economically, the toll of air pollution in India is staggering. [5] estimated a loss of about 1.36% of GDP, equivalent to approximately Rs. 2,78,640 crores due to deaths due to air pollution. This amount exceeds four times the distribution of healthcare in the Union budget for 2020-21. Diseases linked to air pollution have adversely impacted economic growth through reduced productivity, decreased labor supply, and increased health expenditure. The financial loss is valued to affect state GDP, ranging from 0.67% to 2.15%, with a more pronounced impact on low per capita GDP states such as Uttar Pradesh, Bihar, Rajasthan, Madhya Pradesh, and Chhattisgarh. Notably, Delhi experienced the highest per capita economic loss due to air pollution, followed by Haryana. [5]

In 2020 two wheelers accounted for 77.9% of all registered vehicles, outpacing mass transportation system such as buses. Therefore, the sudden growth in automobile sector has caused variety of problems, including traffic congestion, fossil fuel consumption, and so air pollution [5]. Fig 1.1 shows the percentage distribution of all vehicles categories as on 31st March, 2020 where others include three-wheeler (autorickshaws and other miscellaneous vehicles.

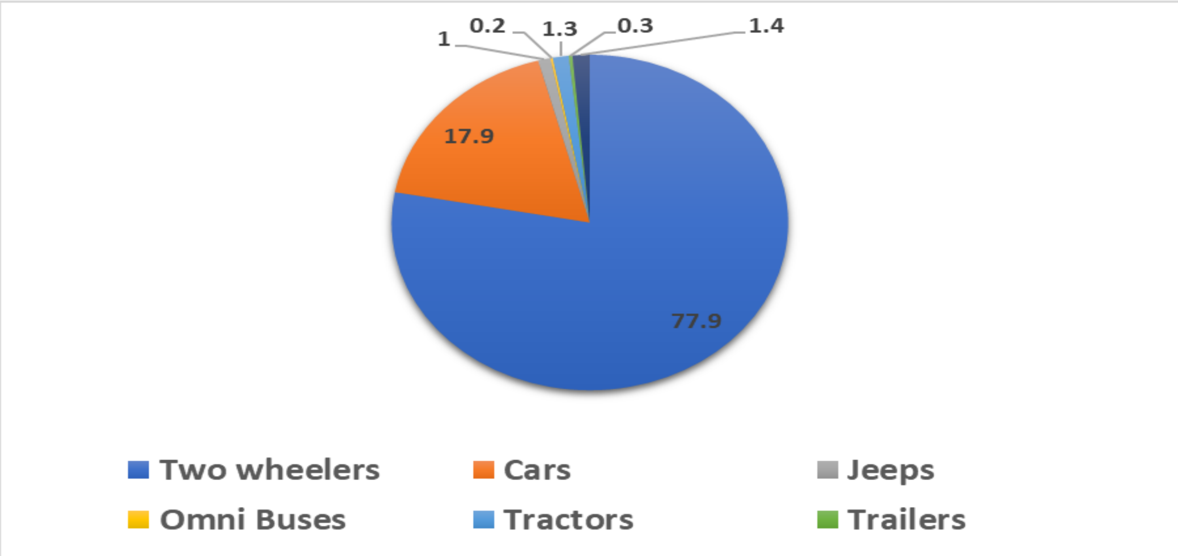


Fig 1.1 Category wise vehicle distribution in India [29]

Road vehicle traffic comprises both people and freight movement, which is used to transport commodities from one location to another. This has led to a substantial rise in travel demand as well as increase in vehicular population. Fig 1.2 shows the number of registered vehicles in India's million-plus population cities in 2019-20, with Delhi having the highest proportion of 5.22% (11.89 million) of total registered vehicles in India.

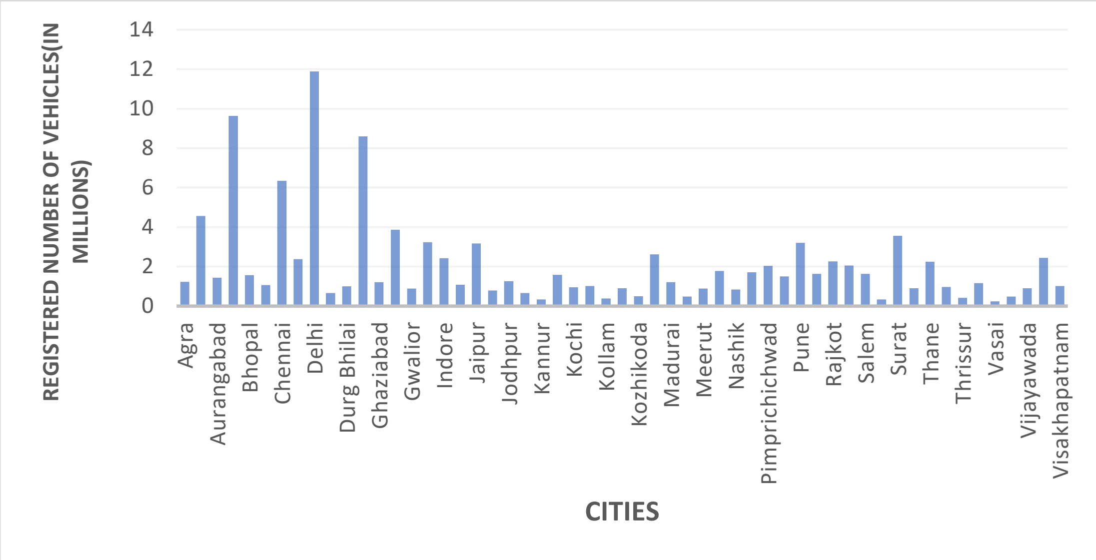


Fig 1.2 Status of registered vehicles in million plus cities [29]

The NCT Delhi covers an area of 1483 km2 and has a population 20 million with a rising economy [28]. The number registered motor vehicles in Delhi had touched up to 10 million as of 2018 [27]. Every day, Delhi sees a substantial influx of light and heavy trucks from national highways like NH-1, NH-2, NH-8, NH-10, and NH-24, making the transportation sector the primary contributor to the city's poor air quality. The issue is compounded by various factors including defective road layouts, outdated engine technologies, poorly maintained vehicles, erratic driving behaviors, and congestion caused by a mix of traffic types and slow-moving vehicles. These conditions lead to high levels of traffic-related air pollution.

The air quality crisis in Delhi ranked as the most polluted capital globally, has become a significant social and political concern in India. Despite numerous studies, there remains limited consensus on the primary sources of air pollution in the city. Road transport, including a large national vehicle fleet concentrated in a small area, is identified as a major contributor, alongside residential activities, open waste burning, and industrial fuel combustion. Despite efforts to curb on-road emissions through interventions and improved vehicle and fuel standards, the escalating number of vehicles continues to challenge air quality improvements. The city's total registered vehicle fleet increased fivefold from 1990 to 2018, reaching an expected 13.0 million by 2022. Initiatives like the Pollution-Under-Check (PUC) program and the Odd–Even experiment have shown limited success, emphasizing the need for comprehensive, effective measures. The introduction of the Delhi Electric Vehicles Policy in 2020 aims to promote electric vehicle adoption, offering financial incentives and plans for scrapping old vehicles. The policy targets 30% of new vehicle registrations being battery electric vehicles by 2030. Despite challenges, Delhi has made strides with a growing on-road EV fleet, highlighting the city's commitment to addressing air pollution and promoting sustainable transportation.

Greenhouse effect is mainly caused by CO_2 (carbon dioxide). It is present in the environment and has lifespan of 50-100years. From the starting of the industrialization there is 67% increase in concentration of CO_2, from 280 ppm in 1750 to 415 ppm in 2019 [8]. Sources of CO_2 in ambient air are fossil fuel combustion, vegetation, vehicular emissions and biogenic cycles. Road transport and industrial activities contribute 70% of total global CO_2 emission in which transport sector is responsible for 25%−30% emissions [10] [11] Increase in CO_2 concentration results irreversible change in climate and responsible for rise in temperature at earth atmosphere.

1.2 Need of the study/ Motivation of the study

Vehicular emissions are significant contributors to urban air pollution and require immediate attention to prevent its adverse impact on the environment and human health. Delhi faces a critical issue of air pollution, with vehicular emissions playing a significant role in exacerbating the problem. Due to the tremendous increase in the number of vehicles in Delhi, there is an increase in pollution load in Delhi, the vehicle load is hence estimated by the emission factors given by using VKT based emission factors CPCB, 2015 to estimate the loads of various pollutants like CO, HC, NO, PM and CO_2 and estimates changes in emission load due to introduction of various policy to curb vehicular pollution.

CHAPTER 2

LITERATURE REVIEW

To analyze the study done so far in the estimation of vehicular emission in Delhi through VKT Based Emission Factors for Different Categories of Vehicles (CPCB, 2015) and IPCC Emission Factors (IPCC, 2006) approach method and further evaluate the reduction in emission due to the introduction of various policy interventions in Delhi to combat air pollution.

Table 2.1: Summary of Relevant Literature Review

S.No.	Highlight	Reference
1.	● This study shows an analysis of the impact of the Bharat stage (BS) in reducing vehicular emissions in Delhi. ● Light-duty vehicle (LDV) emissions were higher than the heavy-duty vehicle (HDV). ● PM2.5 and VOC emissions decreased in the 2017-2022 age group compared to the 2012- 2017 age group.	[11]
2.	● Impact of different policy scenarios on pollution level in the Mumbai metropolitan region. ● An increase in vehicle operating costs would reduce CO_2 emission by 4% compared to BAU SCENARIO IN 2050.	[12]
3.	● The study aimed to assess traffic characteristics and examine the effect of subtle changes made around five metro stations in Delhi. ● The result expected a daily saving of petrol, diesel, and CNG with a 3.5 tonne/day reduction of CO_2.	[13]
4.	● It was a novel study to estimate emission factors specifically for idling conditions, which form a significant portion of vehicular emission. ● Emission factors for CO, NO, CO_2 and unburnt hydrocarbon were estimated by using an emission analyzer attached to the vehicle tailpipe. The results were then compared with relevant literature.	[14]
5.	● Mumbai's current vehicular emissions were calculated and future emissions levels were estimated for the year 2030 considering various policies and interventions like an introduction to the BSVI emission standard, phasing out vehicles with age, and electric vehicles by 30% by 2030. ● The result showed that even after a decrease in tailpipe emissions	[15]

	the total vehicular emissions did not reduce mainly PM due to a significant increase in non-exhaust vehicular emissions.	
6.	• Estimates benefits of non-motorized transport NMT- favorable infrastructure in fuel consumption reduction. • It showed a significant reduction in fuel consumption, emission load and carbon dioxide equivalent.	[17]
7.	• In this study it estimates the shift towards non-motorized transport. • These estimates were made for both pre and post COVID scenario with locking and unlocking phases.	[16]
8.	• The combined effect of electric vehicles (EVs) and other scenarios in reducing CO_2 emissions and fulfilling emission targets for 2030 and 2050 were analyzed. • Results show that only an 18-41% reduction of CO_2, which was not sufficient to achieve the targets.	[18]
9.	• The objective of the study was to quantify the reduction of vehicular emissions and traffic diverted due to the construction of the Eastern Peripheral Expressway (EPE). • Vehicle emission was quantified using a VKT-based emission factor. • The result depicted that there was a reduction in total vehicular emissions load in Delhi.	[19]
10.	• Estimates vehicular emission in Lucknow city in a residential area. • Pollutants were estimated by using Bharat stage IV emission factors.	[20]
11.	• Emission factor is compared for conventional automobiles and electric vehicles (EVs) and emissions are estimated for a period of 45-year horizon (2005-2050). • Electric vehicle could reduce CO_2 generation by 14-100% if electricity generated by renewable source of energy.	[21]
12.	• The study estimates the loss of due to the idling of vehicles, the location of the study was at the Lodhi Road intersection. • CAL3QHC mathematical model was used to predict vehicular pollutants.	[22]
13.	• A study was conducted at multiple traffic intersections in Delhi to calculate idling fuel loss. • A total of 9036 liters of diesel, LPG, and Petrol loss and 5461 kg of CNG loss occurred due to idling. • A total of 37 tonnes of CO_2 eq/day. Were estimated.	[23]
14.	• The study aimed to analyze the status of pollution in Kerala by estimating the vehicular emissions in the study area and recommending ways of reducing emissions.	[24]

	• The emission values for future years 2030 and 2040 were obtained by using emissions values obtained between 2010 to 2018.	
15.	• he VKT approach of different states of india from 2001 to 2013. • There was an increase in the level of pollutant during the study period due to an increase in vehicle population. • States like Gujarat, Tamil Nadu, Kerala, Uttar Pradesh, Rajasthan, Delhi, Karnataka, Andhra Pradesh, and Maharashtra were responsible for 68% of the total studied pollutants.	[25]
16.	• Change in emission factor and emission rates was studied in Delhi. • Results suggested that 2W and cars were the largest contributors to the pollutants and 65% of CO emitted was by 2W, 32% of NOx was because of CNG cars and 43% of PM10 was due to HCV.	[26]
17.	• Emission data for the city of Delhi was calculated from 2000-2005 to quantify vehicular emissions and check the effectiveness of policy changes on emissions of air pollutants. • CO level increased in the study period while the other pollutants declined in the initial year. • NOx and TSP did not show a rise during the study period indicating the effectiveness of CNG as a less alternative fuel.	[27]

Different approaches to quantify vehicular emissions were found in the literature review (table 2.1). In the majority of the studies, emissions have been estimated by either VKT Based Emission Factors for Different Categories of Vehicles (CPCB, 2015) or IPCC Emission Factors (IPCC, 2006). A novel study to estimate emission factors specifically for idling conditions was carried out by [14]. VKT approach estimated vehicular emissions across various Indian states during 2001-2013, showing increased pollutant levels due to rising vehicle numbers, with Gujarat, Tamil Nadu, Kerala, Uttar Pradesh, Rajasthan, Delhi, Karnataka, Andhra Pradesh, and Maharashtra contributing 68% of the total studied pollutants [25]. In another study related to India's climate budget, the study analyzes the combined effect of electric vehicles (EVs), improving electricity grids and minimizing transmission and distribution loss in reducing CO_2 emission and fulfilling emission targets for 2030 and 2050 and there was only an 18-41% reduction of CO_2 , which was not sufficient to achieve the targets [11]. Mumbai's vehicular emissions for 2030, factoring in policies like BSVI standards, vehicle phase-outs, and 30% electric vehicle adoption, indicate persistent total emissions, with non-exhaust emissions notably increasing PM levels despite reduced tailpipe emissions [15]. Vehicular emissions in a residential area of Lucknow city were estimated using Bharat stage IV emission factors to assess pollutant levels [20]. The study on emission factors and rates in Delhi revealed that two-wheelers and cars were the primary contributors to criteria pollutants, with 65% of CO emissions attributable to two-wheelers, 32% of NOx emissions from CNG cars, and 43% of PM10 emissions from heavy commercial vehicles (HCV) [26]. [17] [16] conducted a series of studies focusing on the impact of infrastructure changes around metro stations in Delhi, specifically examining the shift towards non-motorized transport (NMT). Their research estimated the benefits of NMT-friendly infrastructure, revealing significant reductions in fuel consumption, emission load, and carbon dioxide equivalent. Additionally, they assessed traffic characteristics and the effect of subtle changes around five metro stations, predicting a daily reduction in petrol, diesel, and CNG usage along with a notable decrease of 3.5 tonnes/day in CO_2 emissions. Their work extends to considering both pre- and post-COVID scenarios, incorporating phases of lockdown and unlocking to estimate the influence on transportation patterns and environmental outcomes. These studies collectively highlight the positive impact of infrastructure improvements on promoting sustainable and environmentally friendly modes of transport in urban settings like Delhi. The impact of Bharat stage regulations on reducing vehicular emissions in Delhi, finding higher LDV emissions and a decrease in PM2.5 and VOC emissions among newer vehicles (2017-2022) compared to older ones (2012-2017) [11].

2.1 Research Gap(s)

The estimation of vehicular emissions in Delhi under various policy scenarios aimed at combating air pollution has not yet been comprehensively studied. Therefore, a detailed study is necessary to evaluate the effectiveness of different policies in mitigating air pollution in Delhi.

2.2 Scope of the study

The scope of the study is to know effectiveness of proposed policy measures in controlling vehicular emission along a selected urban corridor which is CRRI intersection (which can then be used for whole City Level Analysis) (in terms of Reduction in Vehicular emission Loads (kg/day) of different pollutants and ultimately in terms of air quality (micrograms/m3).

2.3 Objectives of the study

- To assess the emission load along a road corridor in Delhi in terms of CO, HC, PM, NOx and CO_2 by using VKT (Bottom-up Approach) Based emission factors.
- Develop scenarios and analyze the change(s) in emission load due to proposed policy change(s) to control the vehicular pollution on a selective road corridor.

- Compare all the scenario with BAU scenario to find the effectiveness of the scenario as per the policy (Introduction to electric vehicles (EVs), Compressed Natural Gas (CNG) vehicles, increased adoption of BS-VI compliant vehicles, and phased-out older, polluting vehicles, etc).
- After assessing the obtained results, we can evaluate the effectiveness of the policy.

2.4 Novelty

- Calculated the vehicular emission load for Delhi intersections for the year 2024 based on new estimated traffic volume counts.
- Used Euro 6 emission factors to determine the emission load according to the latest BSVI norms.
- Developed various policy scenarios to assess their viability and long-term effectiveness.
- Projected the potential reduction in emission load if the proposed policies are implemented which would help us move towards the policy.

CHAPTER 3

METHODOLOGY

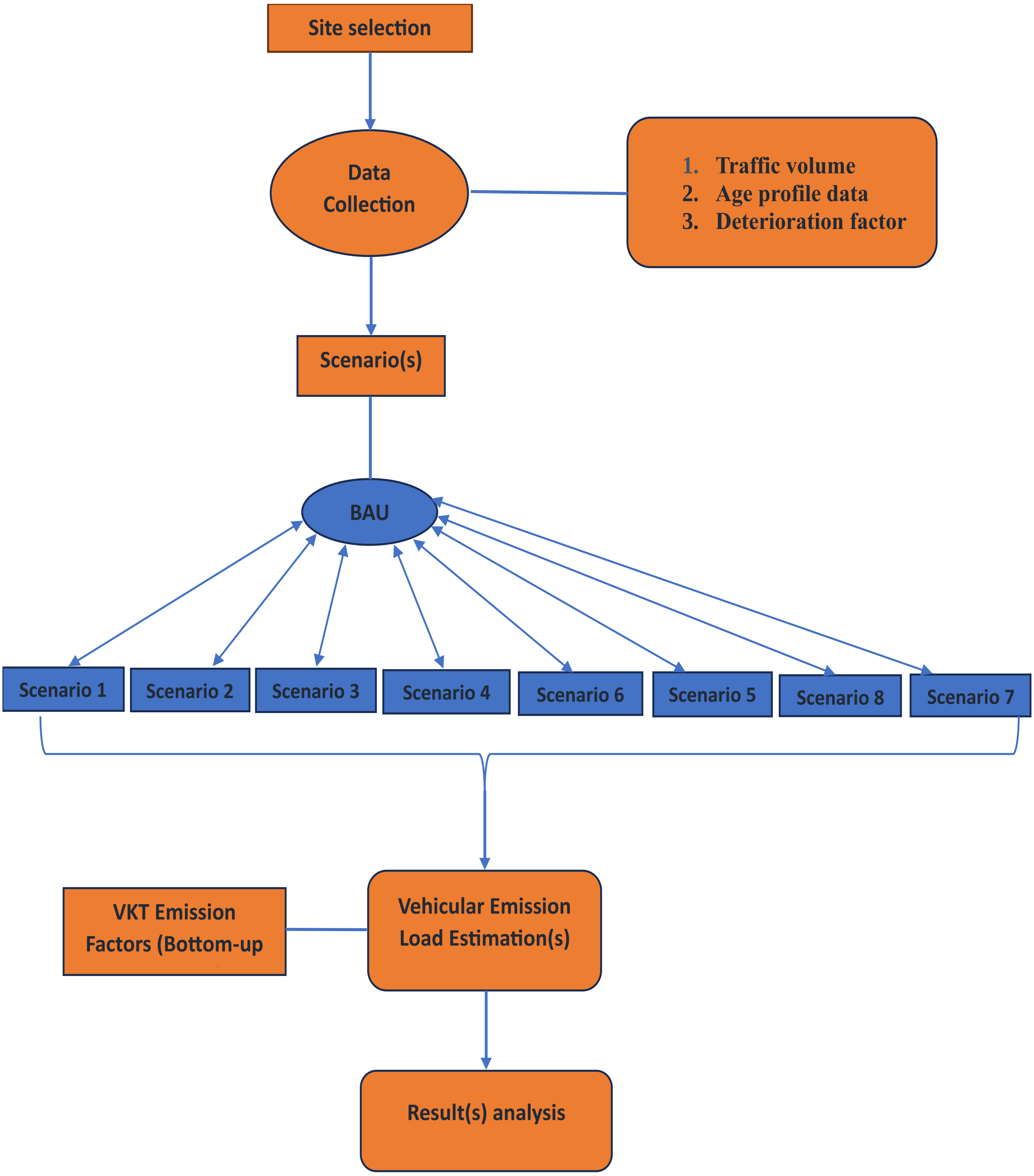


Fig. 3.1: Methodology

In fig 3.1 a methodology chart had been shown we start from site selection to data collection in which we require traffic volume data, and age profile data then with the help of the data we analyze the data with CPCB VKT method for emission load estimation and the it is estimated with 8 different scenarios. After analyzing all 8 scenarios with BAU scenario the change is estimated by calculating using MS Excel sheets. The study has been carried out at one of the busiest road sections of Delhi city which is part of Mathura Road at NH-19 (Delhi to Agra), near the Central Road Research Institute (CRRI). The study area is dual carriageway, which is straight road with flat terrain. The study site connects Faridabad to ashram chowk on another side. The present highway corridor covers an urban area characterized by dense population, commercial and residential development, and various industrial units nearby. The dual carriage is connected through median lane (mid-block), in front of CRRI gate with signalized intersection (Fig 3.2). Signalized intersections are essential components of urban traffic management. Having signalized intersection allows to assess the congestions and its impact on emissions. In this study we have used secondary traffic volume and Age Profile data to estimate the current traffic volume conditions. A growth rate of 1.5 was considered, as there was COVID period from 2020-2022 (i.e. no change in growth rate of vehicle) and small amount of growth in 2023-24. we have assumed year(s) of vehicle up to past 15-year(s) from 2024 that will run on road because of All petrol vehicles older than 15 years and diesel vehicles older than 10 years are considered end-of-life (ELV) vehicles in Delhi. The methodology adopted in estimating vehicular pollution is VKT Based Emission Factors for Different Categories of Vehicles (CPCB, 2015) and IPCC Emission Factors (IPCC, 2006). Then it will be further evaluated on the basis of reduction in emission due to the introduction of various policy interventions in Delhi to combat air pollution. Various policy scenario will be considered to estimated vehicular emissions with BAU (Business as usual) scenario. The policy scenario that would consider are Introduction to electric vehicles (EVs), Compressed Natural Gas (CNG) vehicles, increased adoption of BS VI compliant vehicles, and phasing-out older, polluting vehicles etc. Further results obtained would be calculated in terms of CO_2 equivalent

3.1 Study Area

- **CRRI Traffic Intersection**

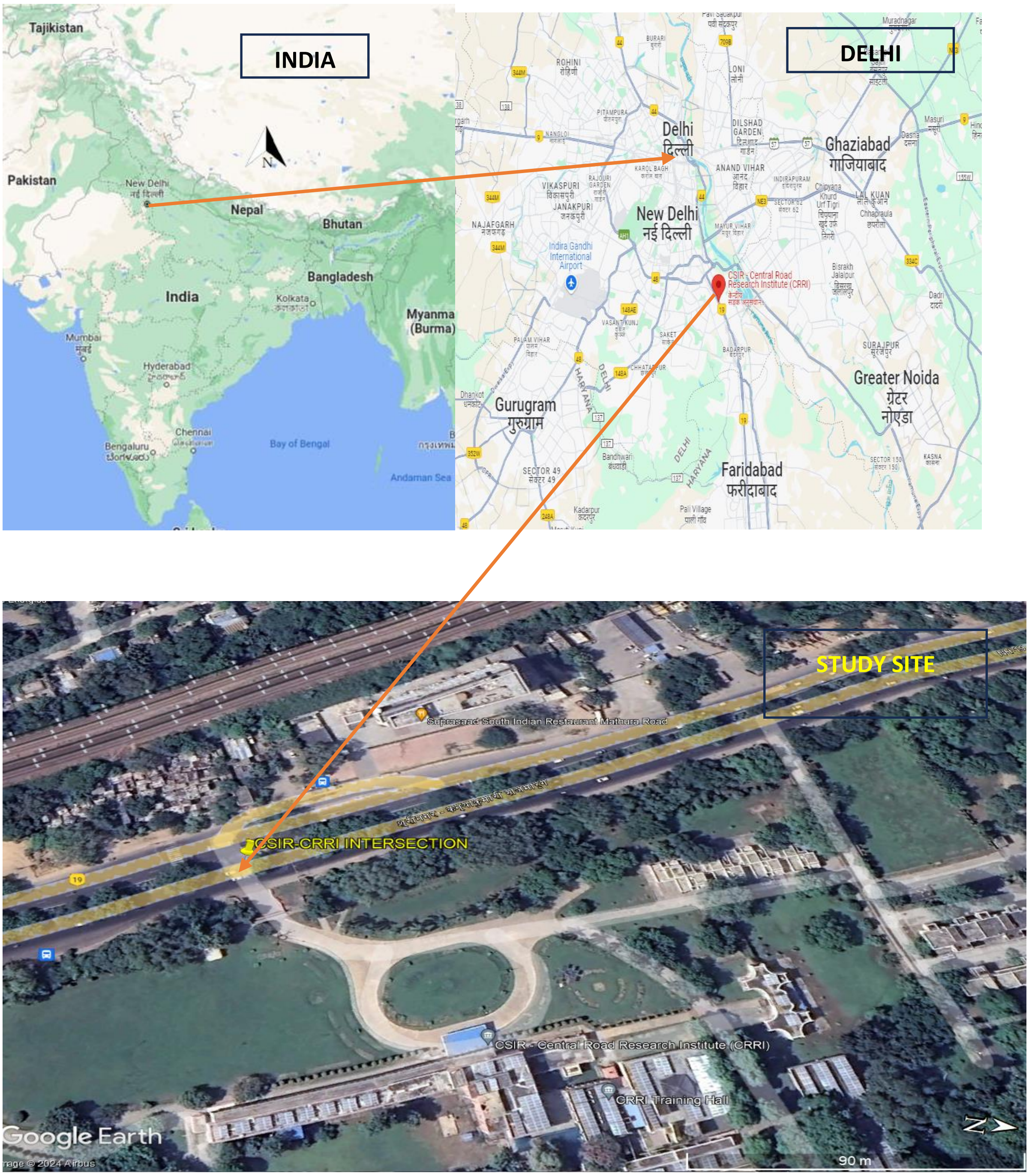


Fig. 3.2: Location of study site; **Source:** Google maps

3.2 Site Characteristics

3.2.1 CRRI Traffic Intersection

The selected intersection is three-armed intersection and is located (28°33'03.0"N 77°16'27.6"E) on National Highway (NH-2) (Delhi to Agra Highway) passing through the Delhi city near CRRI Campus (Fig. 3.3). The section of NH-2 on which intersection is located, caters both inter-city and intra-city vehicular traffic. The CRRI is a high-volume intersection with an average estimated traffic volume of ~1,60,000 vehicles on daily basis. The study corridors do not cater to intercity goods commercial vehicles during peak hour of the city (morning and evening) due to restriction for commercial / goods vehicles enforced by traffic authorities to avoid traffic congestion caused by the movements of heavy commercial vehicles during day-time and are allowed to enter into the city only during specified time period (2100 to 0600 hour). It is not a major intersection in terms of traffic movement (left or right etc.) as the main purpose of this intersection is to cater to the nearby office premises and facilitate pedestrian crossing. The traffic Intersection has adjoining pollution monitoring station (in CRRI campus) which is operated by IMD.

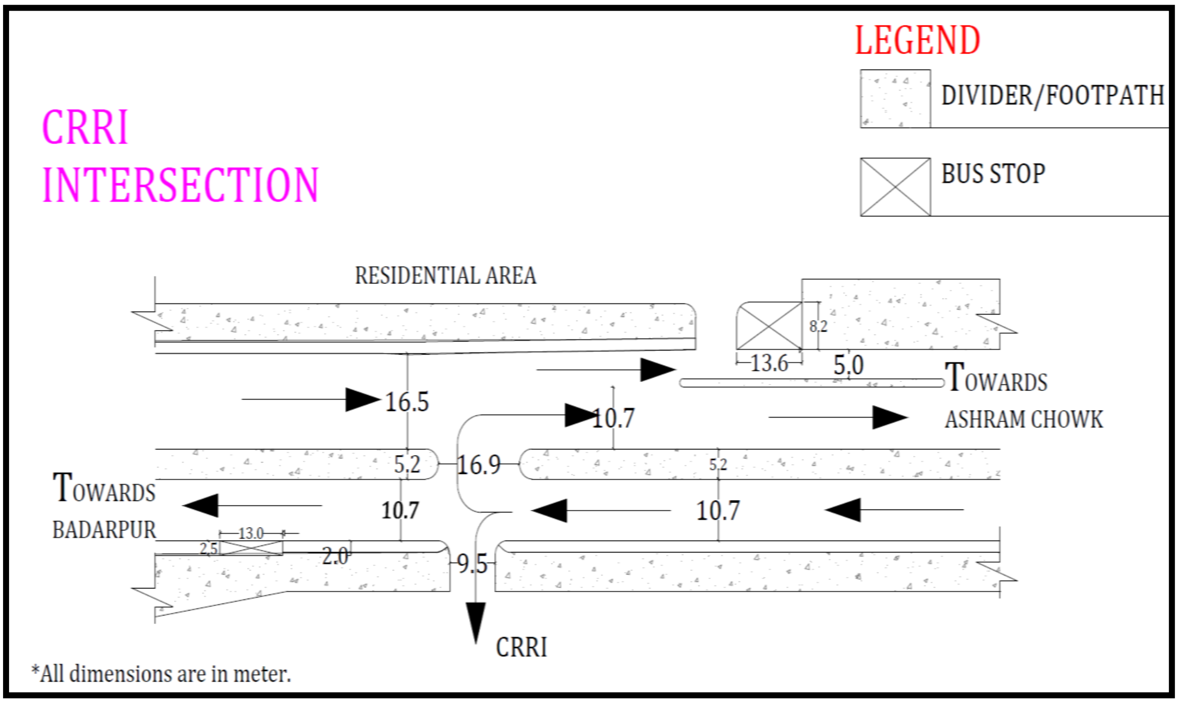


Fig 3.3: Lay out Plan of CRRI Main Gate Traffic Intersection on NH-2

3.3 Estimated Traffic Characteristics

The traffic data has been estimated and presented in hourly basis for different categories of vehicles (viz., Cars, 2Ws, 3Ws, LCVs, Trucks & Buses) and these were combined to estimate hourly traffic and total traffic encountered by each intersection. Further, based on the fuel station survey results, total number of Cars were further classified into Petrol, diesel and CNG Cars, based on their fuel use types. Similarly, Buses, Trucks and LCVs were further sub-classified into Diesel and CNG mode based on the fuel station survey results which have been taken as secondary data for the present study. As, now a day, all the 2Ws are mostly 4-Stroke engine and almost negligible percentage of 2- Stroke engines, all the 2Ws have been grouped into 4-Stroke engine category. The estimated Hourly traffic volume on weekend and weekdays have been presented in Table 3.1 and Table 3.2. The maximum traffic was observed after estimation was during afternoon hours i.e., 13-14 hours (Weekend) and 18-19 during evening hours on Weekday. The total traffic during weekday was observed to be ~23% higher than the weekend traffic. The Projected Diurnal variation of the hourly traffic volume during weekend and weekday has been shown in Fig.3.4. Further, Fig.3.5 present the estimated percentage of different categories of vehicles (i.e. 2Ws, 3Ws, Cars, LCVs, Trucks and Buses) at the CRRI intersection during weekend and weekday. On both the days Cars dominate the share of traffic at the intersection followed by 2Ws, 3Ws, LCVs, Buses and Trucks. The comparison of different categories of vehicles on weekend and weekday in terms of their numbers (i.e. volumes) has been presented in Fig.3.6.

Table 3.1: Estimated Hourly Traffic Volume at CRRI Intersection on Weekend (Projected data for 2024) [31]

Time	Two-Wheeler	Four-Wheeler (Car)			3W	Bus		Truck		LCV		Total
	4-stroke	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel	
	100%	63%	27%	10%	100	71%	29%	8%	92%	72%	28%	
00—01	628	1253	537	199	260	11	5	28	330	274	107	3632
01—02	376	1027	441	163	213	18	8	50	567	235	91	3190
02—03	225	734	315	117	157	13	6	43	495	215	83	2404
03—04	249	555	238	88	134	18	8	32	370	191	74	1958
04—05	447	649	278	103	264	25	10	26	299	223	86	2411
05—06	772	1026	439	162	389	68	27	19	227	229	89	3450
06—07	1213	1472	630	233	547	113	47	9	107	239	93	4702
07—08	1884	1864	799	295	795	145	59	8	89	233	91	6263
08—09	2194	1977	848	314	678	139	57	5	62	179	70	6522
09—10	3022	2178	934	346	847	115	47	4	48	197	76	7812
10—11	2857	2433	1042	386	944	124	51	5	57	235	91	8226
11—12	2514	2857	1225	454	1048	88	37	6	76	285	111	8702
12—13	2315	3017	1293	479	1190	94	39	8	92	305	118	8949
13—14	2670	3335	1429	530	1017	110	45	6	75	336	131	9684
14—15	2112	2970	1273	472	899	104	43	5	64	314	122	8377
15—16	1924	2977	1276	473	831	108	44	5	62	298	117	8115
16—17	2097	3070	1315	487	945	112	46	3	41	223	87	8427
17—18	2485	3183	1364	505	972	96	40	3	36	195	76	8955
18—19	2804	3217	1378	511	1010	88	37	4	47	168	65	9329
19—20	2826	3208	1375	510	1006	98	40	2	20	142	55	9282
20—21	2760	2683	1150	426	972	104	43	3	29	134	53	8356
21—22	2408	2362	1012	375	862	84	35	2	26	160	62	7387
22—23	1806	2187	938	347	674	73	30	5	53	152	59	6324
23—00	1017	1640	703	261	461	51	20	29	335	193	75	4786
Total	64442	76661	32856	12171	25293	2955	1212	462	5333	7917	3078	157243
%	28	33	14	5	11	1	1	0	2	3	1	100

(Traffic volume count data which was surveyed in June, 2019 was used as a secondary data to estimate present traffic volume count, an overall growth rate of 1.5% was considered, as there was COVID period from 2020-2022 (i.e. no change in growth rate of vehicle) and small amount of growth in 2023-24).

Table 3.2: Estimated Hourly Traffic Volume at CRRI Intersection on Weekday (Projected data for 2024) [31]

Time	Two-Wheeler	Four-Wheeler (Car)			3W	Bus		Truck		LCV		Total
	4-stroke	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel	
	100%	63%	27%	10%	100	71%	29%	8%	92%	72%	28%	
00--01	554	1051	451	166	338	18	7	36	405	142	56	3224
01--02	363	606	260	96	221	21	9	33	383	159	62	2215
02--03	213	389	166	62	165	11	5	27	312	111	44	1505
03--04	161	354	152	56	127	21	8	27	311	173	67	1458
04--05	284	429	184	68	252	26	10	19	218	193	75	1759
05--06	684	707	303	113	511	85	36	14	166	291	114	3025
06--07	1406	1350	579	214	676	165	67	8	97	273	106	4941
07--08	2701	3158	1353	501	1060	173	70	5	60	144	56	9280
08--09	4310	3469	1487	551	1159	140	57	4	47	43	17	11284
09--10	5818	4019	1722	638	1513	121	49	7	78	51	19	14036
10--11	5703	4123	1767	655	1459	119	49	8	89	85	32	14089
11--12	3965	3868	1657	614	1411	108	44	14	162	426	166	12436
12--13	3574	3172	1359	503	1239	114	47	18	206	451	176	10858
13--14	3499	3206	1374	510	1174	111	46	13	157	456	178	10723
14--15	3124	3125	1339	496	1022	113	47	14	159	481	188	10108
15--16	3004	3111	1334	494	1028	138	56	10	121	458	178	9932
16--17	3470	3264	1399	519	989	123	51	8	90	370	144	10427
17--18	4980	4139	1774	657	1147	126	52	7	80	117	46	13124
18--19	7806	4084	1750	649	1192	149	61	3	36	69	27	15826
19--20	6137	3504	1501	556	1078	120	49	4	42	77	29	13097
20--21	5234	2857	1225	454	927	119	49	2	22	202	78	11169
21--22	3448	2391	1025	380	992	126	51	3	36	193	75	8719
22--23	2229	1849	793	293	743	95	40	5	56	179	70	6352
23--00	1302	1295	555	206	510	61	24	24	275	506	197	4956
Total	73970	59523	25510	9452	20931	2403	980	317	3608	5649	2200	204543
%	36	29	12	5	10	1	0	0	2	3	1	100

(Traffic volume count data which was surveyed in June, 2019 was used as a secondary data to estimate present traffic volume count, an overall growth rate of 1.5% was considered, as there was COVID period from 2020-2022 (i.e. no change in growth rate of vehicle) and small amount of growth in 2023-24)

In fig:3.4 it shows flow of the vehicles at the intersection with reference to hour of the day and the peak of vehicle movement is from 9am to 11am and 6pm to 8pm.

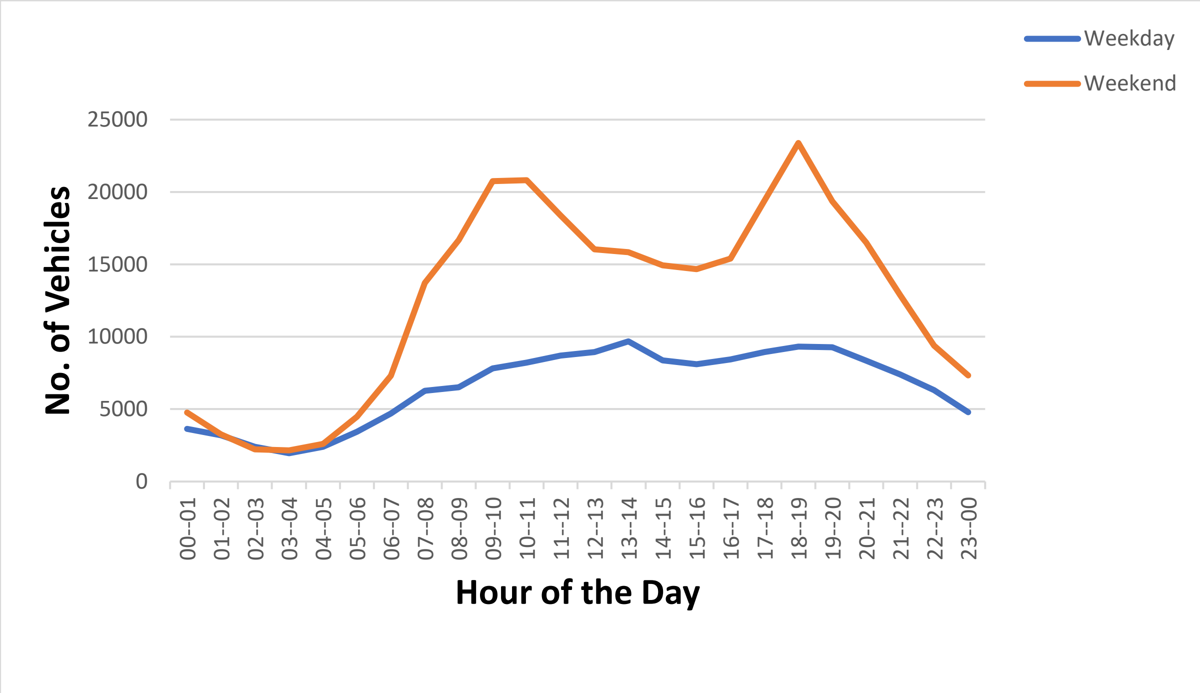


Fig. 3.4: Projected Diurnal Variation During Weekend and Weekday Traffic at CRRI Intersection

Fig: 3.5 shows % share of different categories of the vehicles at weekend and weekday, in weekend car contributed of 52% of the total vehicle followed by 2 wheelers at 28% and in weekday car contribute to 46% and 2 wheelers at 36%.

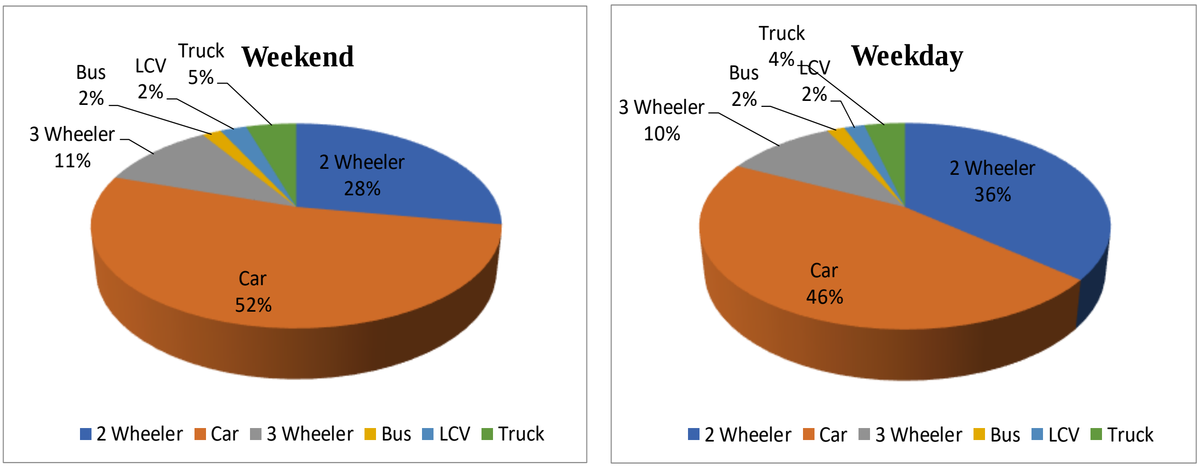


Fig 3.5: Estimated % Share of Different Categories of Vehicles at CRRI Intersection on Weekend and Weekday

Fig. 3.6: Shows the projected value of different Categories of Vehicles, where the intersections was dominated by the four wheelers and two wheelers followed by 3 wheelers, LCVs, truck and then buses.

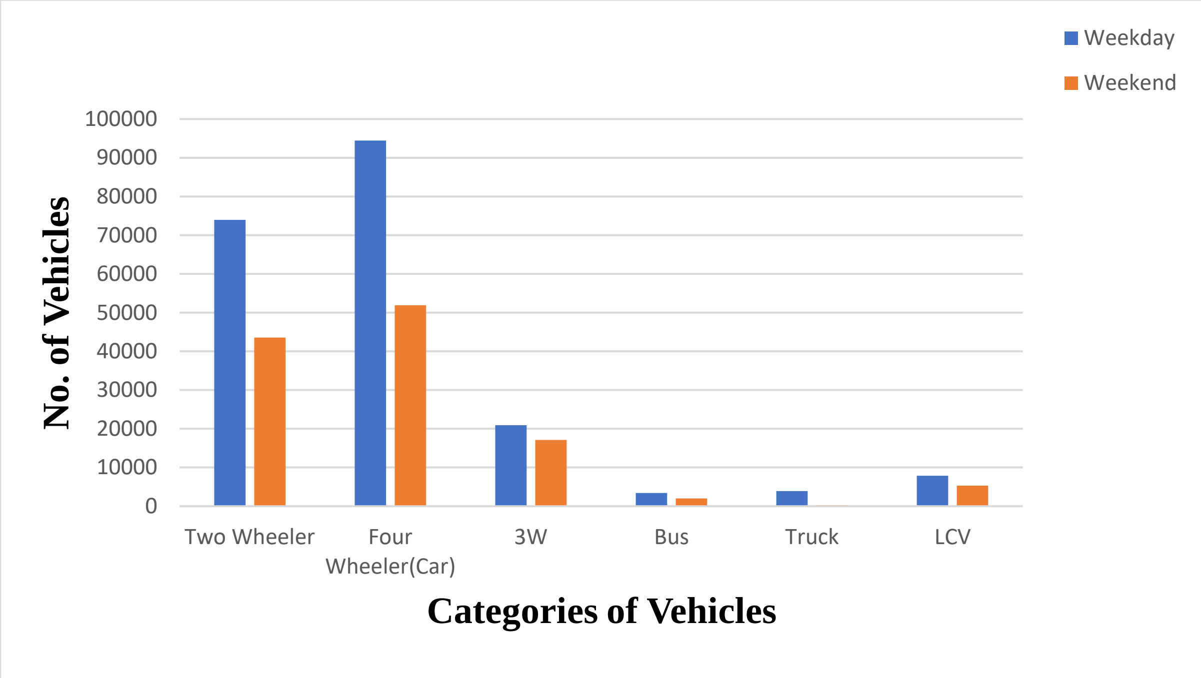


Fig. 3.6: Estimated Comparison of Different Categories of Vehicles on Weekend and Weekday at CRRI Intersection at CRRI Intersection

3.4 Age and fuel distribution of vehicles

The present study requires detailed data related to vehicle characteristics of different categories of vehicles was obtained from secondary data. Information like category of vehicle, type of vehicles, age of vehicles, fuel type. The Age profile data (Table 3.3 and Table 3.4). which was surveyed in June, 2019 was used as a secondary data to assume the current age profile data, we have assumed year(s) of vehicle up to past 15-year(s) from 2024 that will run on road because of All petrol vehicles older than 15 years and diesel vehicles older than 10 years are considered end-of-life (ELV) vehicles in Delhi.). It was observed that ~85% of the cars and two wheelers are <10-year-old and ~70 of all categories of vehicles are <10-year-old. Further, ~20 of all categories of vehicles are <5-year-old.

Table 3.3: Assumed Age Profile of Various Categories of Vehicles Obtained from Fuel Stations Surveys [31]

YEAR	Two Wheelers (2W)	Four Wheelers(cars)			3W	Bus		Trucks		LCV	
	Petrol	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel
	100%	63%	27%	10%	100%	71%	29%	8%	92%	72%	28%
2009	0.2	0.2	0.4	1.4	0.7	2.6	0	0	0.2	0	0
2010	0.3	0.3	0.6	0.1	0.7	2.6	0	0	0.4	0	0
2011	0.9	1.2	1.2	1.2	3	2.6	2	0	4.9	0	0
2012	1	1.2	1	2.1	3.4	0	0	0	4.3	0	0
2013	1.5	1.7	1.8	3.7	3.5	5.1	2	0	5.7	0	0
2014	1.6	2.4	1.3	3.9	3.5	10.3	0	2.8	5.3	0	0
2015	1.7	2.4	1.4	4.8	3.4	10.3	2	5.6	6.5	0	0
2016	4.3	4.8	3.3	4.5	5.9	5.1	9.9	16.7	9.6	0	2.2
2017	5.1	4.6	4.4	6.1	5.6	5	5	5.6	6.2	0	10.9
2018	6	8	5.8	7.5	9.4	5.1	4	5.6	7.2	0	8.7
2019	10.2	10.6	9.5	12.4	9.5	10.3	14.9	22.2	10.6	0	9.8
2020	12.6	16.5	14	13	12.3	5.1	23.8	15.7	15.2	0	8.7
2021	18.3	17.8	21.4	16.1	10.8	12.8	13.9	10.5	8.7	25	17.4
2022	14.6	13	13.5	7.8	10.2	0	9.9	4.2	7.5	25	18.5
2023	14.4	11.6	13.9	10.9	9.5	23.1	10.6	8.3	5.5	25	13.1
2024	7.2	3.7	6.4	4.2	8.6	0	2	2.8	2.2	25	10.7
Total (%)	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
no. of vehicle surveyed at fuel station	3,529	4,894	2,089	716	1,039	98	41	39	433	100	100

(The Age profile data which was surveyed in June, 2019 was used as a secondary data to assume the current age profile data, we have assumed year(s) of vehicle up to past 15-year(s) from 2024 that will run on road because of All petrol vehicles older than 15 years and diesel vehicles older than 10 years are considered end-of-life (ELV) vehicles in Delhi.)

Table 3.4: Age Profile (in Different Age Groups) of Various Categories of Vehicles from Fuel Stations Surveys (secondary data) [31].

Age (Years)	Two Wheelers (2W)	Four Wheelers(cars)			3W	Bus		Trucks		LCV	
	Petrol	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel
	100%	63%	27%	10%	100%	71%	29%	8%	92%	72%	28%
15+	2	2	2	3	4	8	2	0	6	0	0
11-15	10	13	9	19	20	31	14	25	31	0	2
6-10	52	58	55	55	48	38	62	60	48	25	56
0-5	36	28	34	23	28	23	23	15	15	75	42

3.5 Vehicular Emission Load Estimation(s)

3.5.1 VKT Emission Factors (Bottom-up Approach)

The vehicular emission at CRRI main gate was quantified based on the number of vehicles and distance travelled per different vehicle type such as 2W, 3W, 4W, Buses, Trucks etc. Then they were segregated based upon fuel type and year on the basis of fuel station survey. The vehicle kilometre travelled (VKT) emission factors (Table 3.5) CPCB (2015) and deterioration factors (CPCB, 2000) were used to estimate the total emission loads of various pollutants viz., CO, HC, NOx, PM and CO_2 .

Table 3.5: CPCB Emission factors*

New Emission Factors[@]							
Type	Engine Capacity	Year	CO (gm/km)	HC (gm/km)	NOx (gm/km)	PM (gm/km)	CO_2 (gm/km)
2W(4S) (Motor Cycles)	<100cc	Post 2000	1.65	0.61	0.27	0.015	23.25
		Post 2010	0.829	0.307	0.136	0.013	24.97
	100-200cc	Post 2000	1.48	0.5	0.54	0.035	24.82
		Post 2010	0.744	0.251	0.271	0.028	24.82
2W(4S) (Scooters)	>100cc	Post 2000	0.93	0.65	0.35	0.015	33.83
		Post 2005	0.4	0.15	0.25	0.015	42.06
		Post 2010	0.268	0.101	0.168	0.01	42.06
3W CNG OEM (4Stroke)	<200cc	Post 2000	1	0.26	0.5	0.015	77.7
Passenger Cars (CNG)	<1000CC	Post 2000	0.6	0.46	0.74	0.006	143.54
Passenger Car LPG	**1000-1400cc**	**Post 2000**	**0.6**	**0.36**	**0.01**	**0.002**	**131.19**
Passenger Cars (Diesel)	<1600cc	2001-2005 BS II	0.3	0.26	0.49	0.06	156.76
		2005-2010 BSIII	0.06	0.08	0.28	0.015	148.76
		2010-2015 BSIV	0.047	0.048	0.14	0.008	148.76
Passenger Cars (Petrol)	1000-1400cc	2001-2005 BS II	3.01	0.19	0.12	0.006	126.5
		2005-2010 BSIII	1.945	0.095	0.054	0.003	126.5
		2010-2015 BSIV	1.294	0.095	0.064	0.002	126.5
Bus CNG	>6000cc	Post 2000	3.72	3.75	6.21	0.044	806.5
		Post 2010	3.72	3.75	4.347	0.035	806.5
Bus Diesel	>6000CC	2001-2005 BS II	3.97	0.39	11.5	0.795	668
		2006-2010 BSIII	3.97	0.39	11.5	0.795	668
		2011-2015 BSIV	3.92	0.16	6.53	0.3	602.01
		2011-2016 BSIV	2.838	0.112	4.571	0.051	602.01
	>6000CC	>2001 BS II	6	0.37	9.3	1.24	762.39

HCV Diesel Truck		BS III	6	0.37	8.63	0.42	762.39
		BS IV	4.345	0.259	6.041	0.071	762.39
LCV (Diesel)	>3000cc	**BS I**	3.66	1.35	2.12	0.475	401.25
		2001-2005 BS II	3.66	1.35	2.12	0.475	401.25
		2006-2010 BSIII	3.66	1.35	2.12	0.475	401.25
		2011-2015 BSIV	2.65	0.946	1.484	0.137	401.25
LCV CNG		2006-2010	3.2			0.026	
		2011-2015	3.2			0.026	
Tractors (Others)			**9.88**	**1.09**	**9.73**	**1.09**	**799.95**

*CPCB (2015). Status of Pollution Generated from Road Transport in Six Mega Cities. Central Pollution Control Board, Ministry of Environment Forest and Climate Change, Govt. of India. (http://cpcb.nic.in/cpcbold /upload New Items /NewItem_215_Report _Statue s_ Road Transport SixCities.pdf)

The emission loads (kg/day) are estimated by using the following equation:

$$E_{i,j} = \sum_{i,j} (n_i * EF_i * DFj * d)/10^3 \qquad \text{(Eq. 3.1)}$$

Were,

i = vehicle category

j = Fuel type

E = Emissions (kg/hr)

n = number of vehicles

EF = Emission factor in (g/km)

DF = Deterioration factor based upon age of the vehicles

d = distance travelled by the vehicle (km)

3.6 Vehicular Emission Under Different Scenario

The vehicular emission load was estimated under different scenario namely: -

Scenario(s)	Scenario No.
Do-Nothing Scenario / BAU (Business as Usual Scenario)	
100% 2-Wheeler into Electric Vehicle Conversion Scenario	Scenario 1
100% 4-Wheeler into Electric Vehicle Conversion Scenario	Scenario 2
100% 4-Wheeler & 2 -Wheeler into Electric Vehicle Conversion Scenario	Scenario 3
50% Petrol, 20% Diesel and 30%- Electric Vehicle Four-Wheeler	Scenario 4
100% Light commercial vehicle into CNG Conversion Scenario	Scenario 5
100% Truck vehicle into CNG Conversion Scenario	Scenario 6
Phasing out vehicles with age >15(petrol) years and >10(Diesel)	Scenario 7
Introduction of BSVI emission standards in 2020	Scenario 8

CHAPTER 4

ANALYSIS

In this chapter the study analyzes the projected data to estimate the emission load for all the scenario. We have used MS Excel to calculate the emission load. The steps followed to estimate the emission load are as follows: -

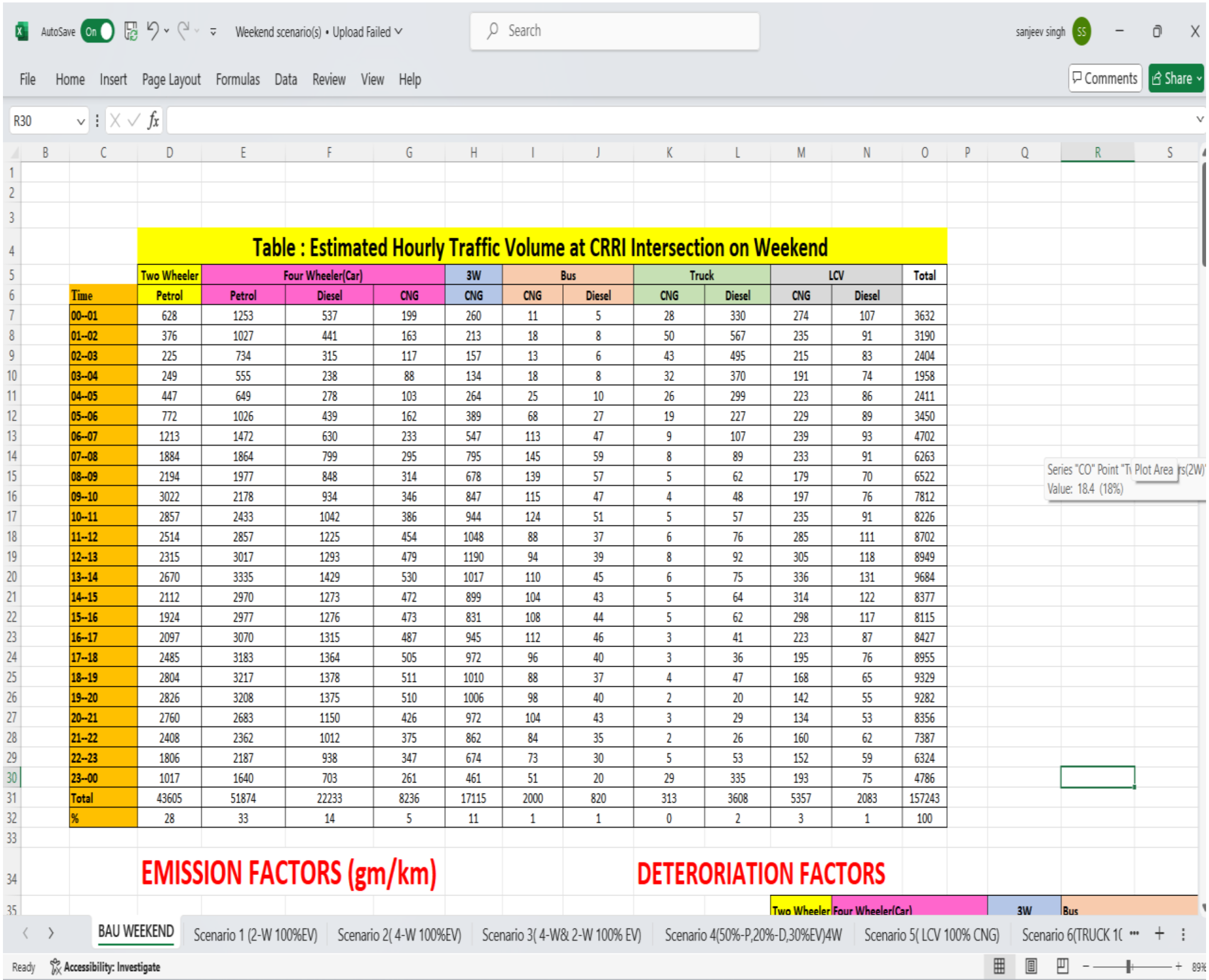
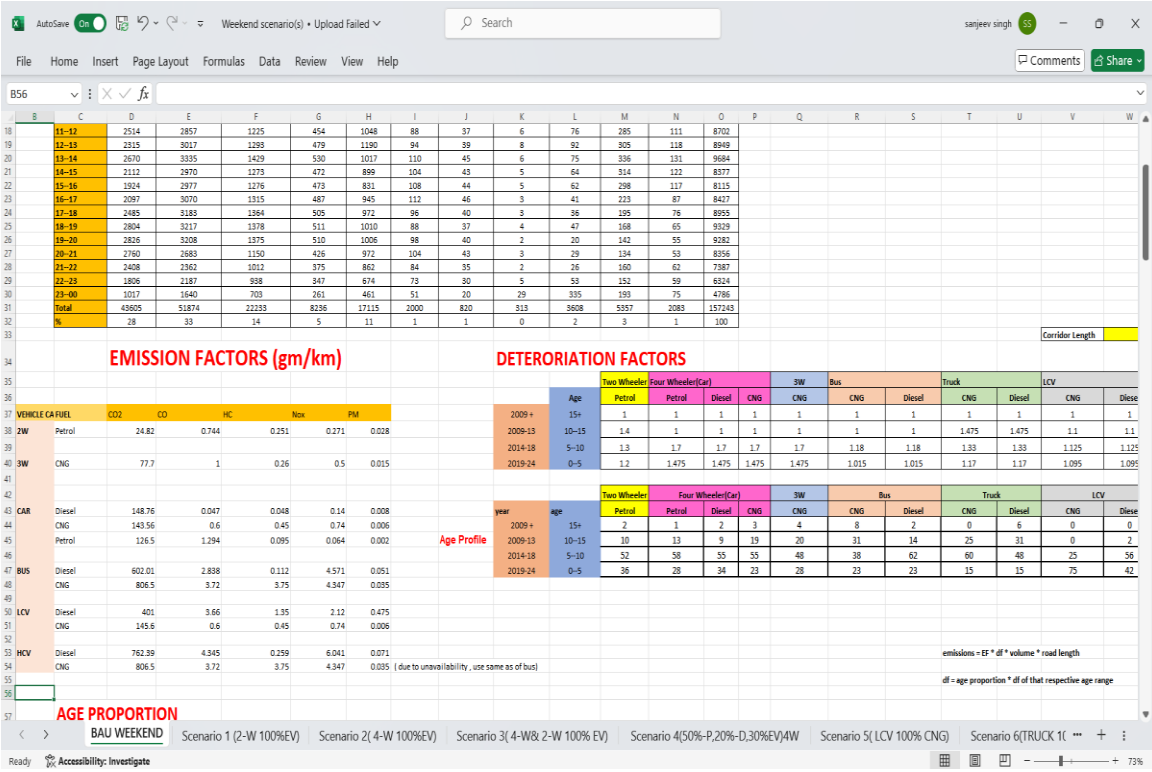


Table : Estimated Hourly Traffic Volume at CRRI Intersection on Weekend

	Two Wheeler	Four Wheeler(Car)			3W	Bus		Truck		LCV		Total
Time	Petrol	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel	
00--01	628	1253	537	199	260	11	5	28	330	274	107	3632
01--02	376	1027	441	163	213	18	8	50	567	235	91	3190
02--03	225	734	315	117	157	13	6	43	495	215	83	2404
03--04	249	555	238	88	134	18	8	32	370	191	74	1958
04--05	447	649	278	103	264	25	10	26	299	223	86	2411
05--06	772	1026	439	162	389	68	27	19	227	229	89	3450
06--07	1213	1472	630	233	547	113	47	9	107	239	93	4702
07--08	1884	1864	799	295	795	145	59	8	89	233	91	6263
08--09	2194	1977	848	314	678	139	57	5	62	179	70	6522
09--10	3022	2178	934	346	847	115	47	4	48	197	76	7812
10--11	2857	2433	1042	386	944	124	51	5	57	235	91	8226
11--12	2514	2857	1225	454	1048	88	37	6	76	285	111	8702
12--13	2315	3017	1293	479	1190	94	39	8	92	305	118	8949
13--14	2670	3335	1429	530	1017	110	45	6	75	336	131	9684
14--15	2112	2970	1273	472	899	104	43	5	64	314	122	8377
15--16	1924	2977	1276	473	831	108	44	5	62	298	117	8115
16--17	2097	3070	1315	487	945	112	46	3	41	223	87	8427
17--18	2485	3183	1364	505	972	96	40	3	36	195	76	8955
18--19	2804	3217	1378	511	1010	88	37	4	47	168	65	9329
19--20	2826	3208	1375	510	1006	98	40	2	20	142	55	9282
20--21	2760	2683	1150	426	972	104	43	3	29	134	53	8356
21--22	2408	2362	1012	375	862	84	35	2	26	160	62	7387
22--23	1806	2187	938	347	674	73	30	5	53	152	59	6324
23--00	1017	1640	703	261	461	51	20	29	335	193	75	4786
Total	43605	51874	22233	8236	17115	2000	820	313	3608	5357	2083	157243
%	28	33	14	5	11	1	1	0	2	3	1	100

Fig 4.1: Projected traffic volume count; Step:1

In fig: 4.1 the projected traffic volume count is put up into the excel sheet for calculation of the emission load and with help age profile, emission factors data and deterioration factor in fig 4.2 we calculate the multiplication factors for further calculation of emission load, with the help of multiplication factors in fig 4.3 we calculate the emission load for the studied pollutants.



	D	E	F	G	H	I	J	K	L	M	N	O
11--12	2514	2857	1225	454	1048	88	37	6	76	285	111	8702
12--13	2315	3017	1293	479	1190	94	39	8	92	305	118	8949
13--14	2670	3335	1429	530	1017	110	45	6	75	336	131	9684
14--15	2112	2970	1273	472	899	104	43	5	64	314	122	8377
15--16	1924	2977	1276	473	831	108	44	5	62	298	117	8115
16--17	2097	3070	1315	487	945	112	46	3	41	223	87	8427
17--18	2485	3183	1364	505	972	96	40	3	36	195	76	8955
18--19	2804	3217	1378	511	1010	88	37	4	47	168	65	9329
19--20	2826	3208	1375	510	1006	98	40	2	20	142	55	9282
20--21	2760	2683	1150	426	972	104	43	3	29	134	53	8356
21--22	2408	2362	1012	375	862	84	35	2	26	160	62	7387
22--23	1806	2187	938	347	674	73	30	5	53	152	59	6324
23--00	1017	1640	703	261	461	51	20	29	335	193	75	4786
Total	43605	51874	22233	8236	17115	2000	820	313	3608	5357	2083	157243
%	28	33	14	5	11	1	1	0	2	3	1	100

EMISSION FACTORS (gm/km)

VEHICLE CA	FUEL	CO2	CO	HC	Nox	PM
2W	Petrol	24.82	0.744	0.251	0.271	0.028
3W	CNG	77.7	1	0.26	0.5	0.015
CAR	Diesel	148.76	0.047	0.048	0.14	0.008
	CNG	143.56	0.6	0.45	0.74	0.006
	Petrol	126.5	1.294	0.095	0.064	0.002
BUS	Diesel	602.01	2.838	0.112	4.571	0.051
	CNG	806.5	3.72	3.75	4.347	0.035
LCV	Diesel	401	3.66	1.35	2.12	0.475
	CNG	145.6	0.6	0.45	0.74	0.006
HCV	Diesel	762.39	4.345	0.259	6.041	0.071
	CNG	806.5	3.72	3.75	4.347	0.035 (due to unavailability, use same as of bus)

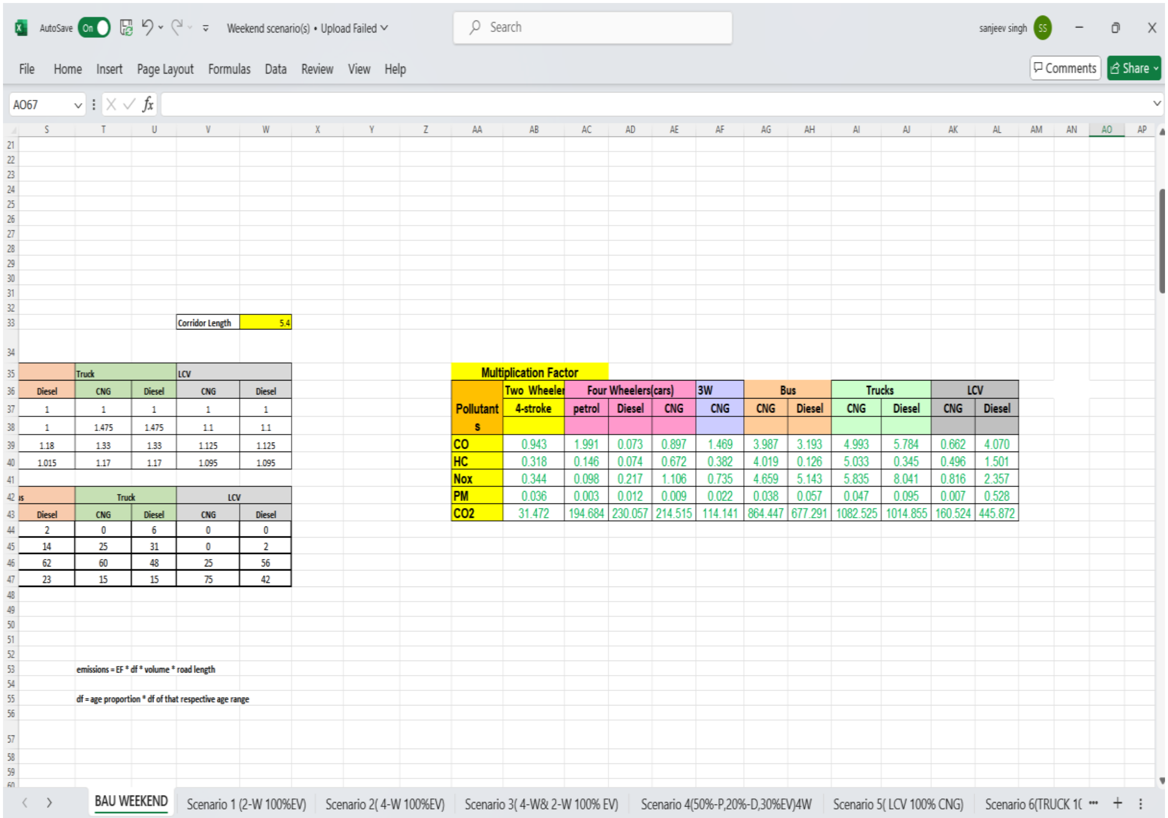
DETERORIATION FACTORS

		Two Wheeler	Four Wheeler(Car)			3W	Bus		Truck		LCV	
	Age	Petrol	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diese
2009 +	15+	1	1	1	1	1	1	1	1	1	1	1
2009-13	10--15	1.4	1	1	1	1	1	1	1.475	1.475	1.1	1.1
2014-18	5--10	1.3	1.7	1.7	1.7	1.7	1.18	1.18	1.33	1.33	1.125	1.125
2019-24	0--5	1.2	1.475	1.475	1.475	1.475	1.015	1.015	1.17	1.17	1.095	1.095

Age Profile

		Two Wheeler	Four Wheeler(Car)			3W	Bus		Truck		LCV	
year	age	Petrol	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diese
2009 +	15+	2	1	2	3	4	8	2	0	6	0	0
2009-13	10--15	10	13	9	19	20	31	14	25	31	0	2
2014-18	5--10	52	58	55	55	48	38	62	60	48	25	56
2019-24	0--5	36	28	34	23	28	23	23	15	15	75	42

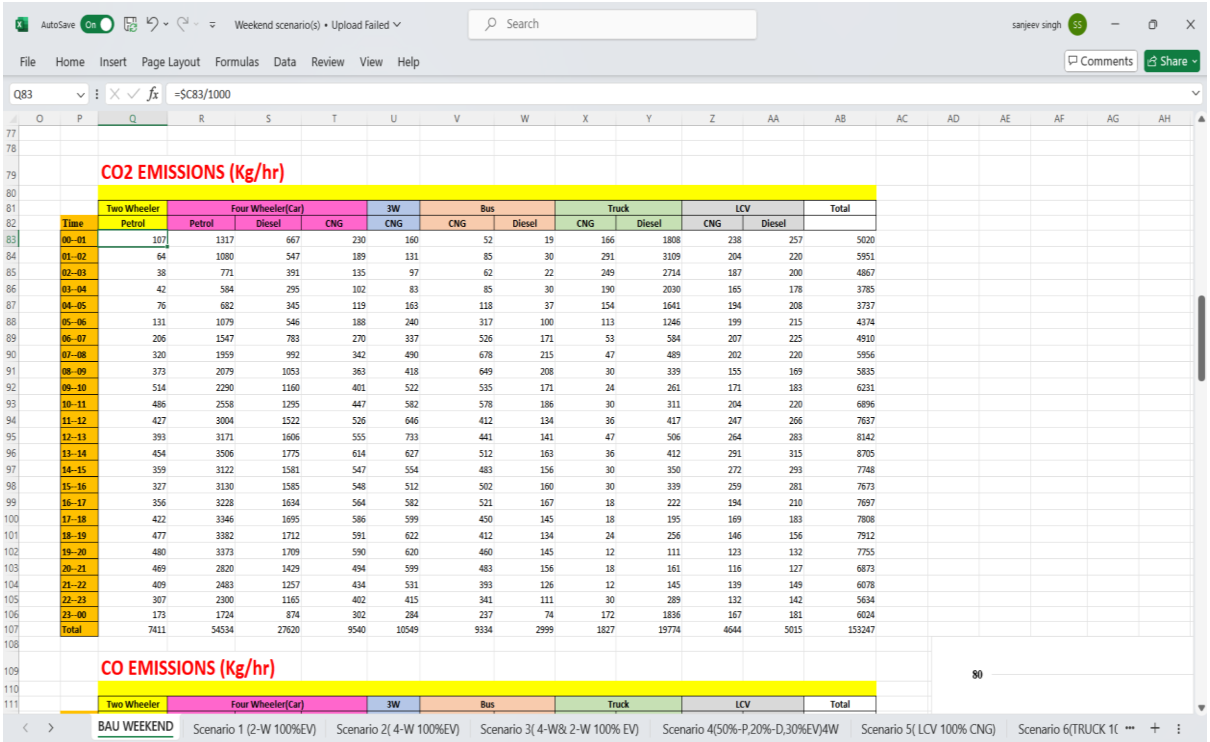
Fig 4.2: Emission factor, deterioration factors and age profile data; Step:2



Multiplication Factor

Pollutants	Two Wheeler	Four Wheelers(cars)			3W	Bus		Trucks		LCV	
	4-stroke	petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel
CO	0.943	1.991	0.073	0.897	1.469	3.987	3.193	4.993	5.784	0.662	4.070
HC	0.318	0.146	0.074	0.672	0.382	4.019	0.126	5.033	0.345	0.496	1.501
Nox	0.344	0.098	0.217	1.106	0.735	4.659	5.143	5.835	8.041	0.816	2.357
PM	0.036	0.003	0.012	0.009	0.022	0.038	0.057	0.047	0.095	0.007	0.528
CO2	31.472	194.684	230.057	214.515	114.141	864.447	677.291	1082.525	1014.855	160.524	445.872

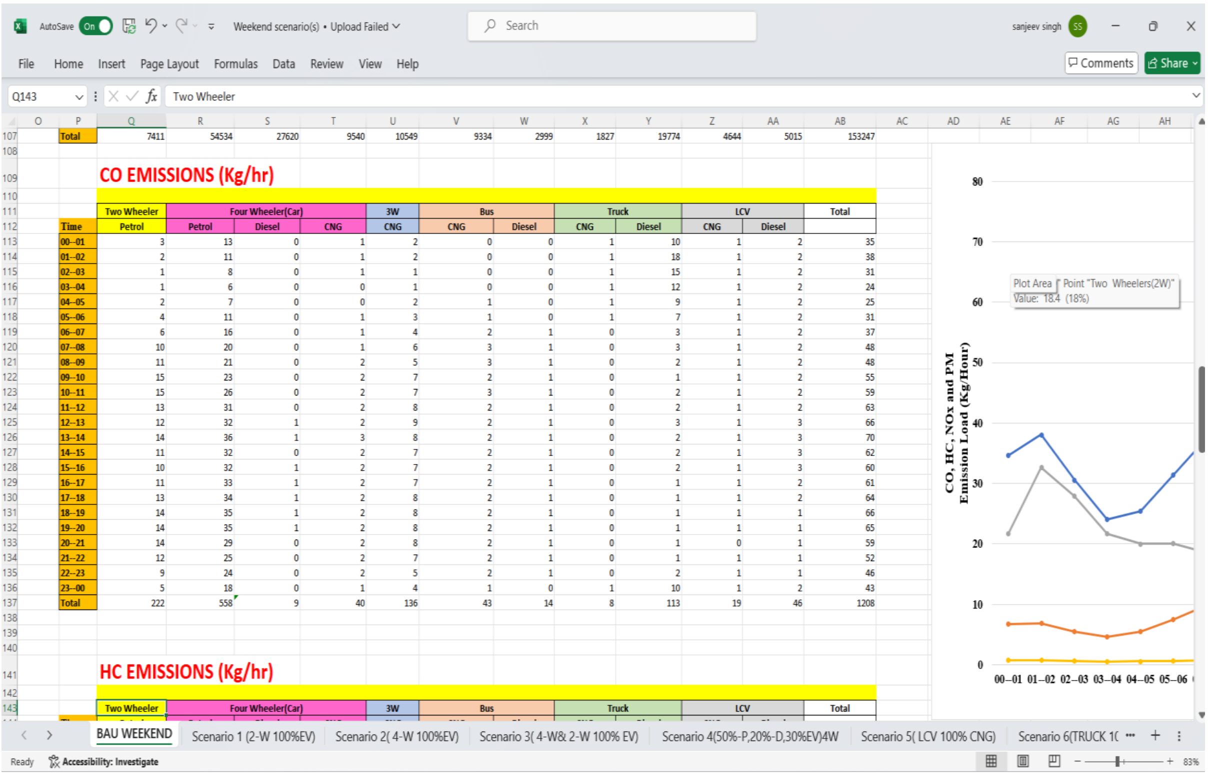
Fig 4.3: Multiplication factor; Step:3



CO2 EMISSIONS (Kg/hr)

Time	Two Wheeler	Four Wheeler(Car)			3W	Bus		Truck		LCV		Total
	Petrol	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel	
00--01	107	1317	667	230	160	52	19	166	1808	238	257	5020
01--02	64	1080	547	189	131	85	30	291	3109	204	220	5951
02--03	38	771	391	135	97	62	22	249	2714	187	200	4867
03--04	42	584	295	102	83	85	30	190	2030	165	178	3785
04--05	76	682	345	119	163	118	37	154	1641	194	208	3737
05--06	131	1079	546	188	240	317	100	113	1246	199	215	4374
06--07	206	1547	783	270	337	526	171	53	584	207	225	4910
07--08	320	1959	992	342	490	678	215	47	489	202	220	5956
08--09	373	2079	1053	363	418	649	208	30	339	155	169	5835
09--10	514	2290	1160	401	522	535	171	24	261	171	183	6231
10--11	486	2558	1295	447	582	578	186	30	311	204	220	6896
11--12	427	3004	1522	526	646	412	134	36	417	247	266	7637
12--13	393	3171	1606	555	733	441	141	47	506	264	283	8142
13--14	454	3506	1775	614	627	512	163	36	412	291	315	8705
14--15	359	3122	1581	547	554	483	156	30	350	272	293	7748
15--16	327	3130	1585	548	512	502	160	30	339	259	281	7673
16--17	356	3228	1634	564	582	521	167	18	222	194	210	7697
17--18	422	3346	1695	586	599	450	145	18	195	169	183	7808
18--19	477	3382	1712	591	622	412	134	24	256	146	156	7912
19--20	480	3373	1709	590	620	460	145	12	111	123	132	7755
20--21	469	2820	1429	494	599	483	156	18	161	116	127	6873
21--22	409	2483	1257	434	531	393	126	12	145	139	149	6078
22--23	307	2300	1165	402	415	341	111	30	289	132	142	5634
23--00	173	1724	874	302	284	237	74	172	1836	167	181	6024
Total	7411	54534	27620	9540	10549	9334	2999	1827	19774	4644	5015	153247

Fig 4.4: Calculation of Emission load of CO_2; Step:4

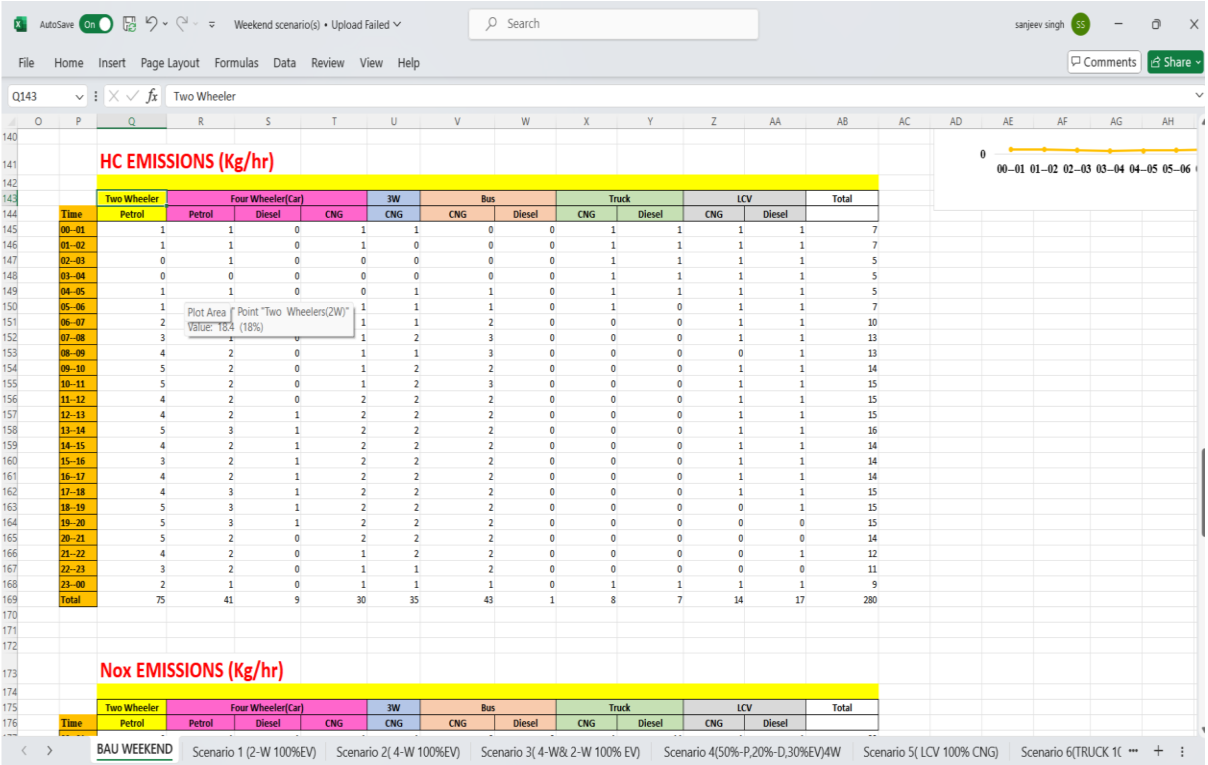


CO EMISSIONS (Kg/hr)

Time	Two Wheeler	Four Wheeler(Car)			3W	Bus		Truck		LCV		Total
	Petrol	Petrol	Diesel	CNG	CNG	CNG	Diesel	CNG	Diesel	CNG	Diesel	
00--01	3	13	0	1	2	0	0	1	10	1	2	35
01--02	2	11	0	1	2	0	0	1	18	1	2	38
02--03	1	8	0	1	1	0	0	1	15	1	2	31
03--04	1	6	0	0	1	0	0	1	12	1	2	24
04--05	2	7	0	0	2	1	0	1	9	1	2	25
05--06	4	11	0	1	3	1	0	1	7	1	2	31
06--07	6	16	0	1	4	2	1	0	3	1	2	37
07--08	10	20	0	1	6	3	1	0	3	1	2	48
08--09	11	21	0	2	5	3	1	0	2	1	2	48
09--10	15	23	0	2	7	2	1	0	1	1	2	55
10--11	15	26	0	2	7	3	1	0	2	1	2	59
11--12	13	31	0	2	8	2	1	0	2	1	2	63
12--13	12	32	1	2	9	2	1	0	3	1	3	66
13--14	14	36	1	3	8	2	1	0	2	1	3	70
14--15	11	32	0	2	7	2	1	0	2	1	3	62
15--16	10	32	1	2	7	2	1	0	2	1	3	60
16--17	11	33	1	2	7	2	1	0	1	1	2	61
17--18	13	34	1	2	8	2	1	0	1	1	2	64
18--19	14	35	1	2	8	2	1	0	1	1	1	66
19--20	14	35	1	2	8	2	1	0	1	1	1	65
20--21	14	29	0	2	8	2	1	0	1	0	1	59
21--22	12	25	0	2	7	2	1	0	1	1	1	52
22--23	9	24	0	2	5	2	1	0	2	1	1	46
23--00	5	18	0	1	4	1	0	1	10	1	2	43
Total	222	558	9	40	136	43	14	8	113	19	46	1208

HC EMISSIONS (Kg/hr)

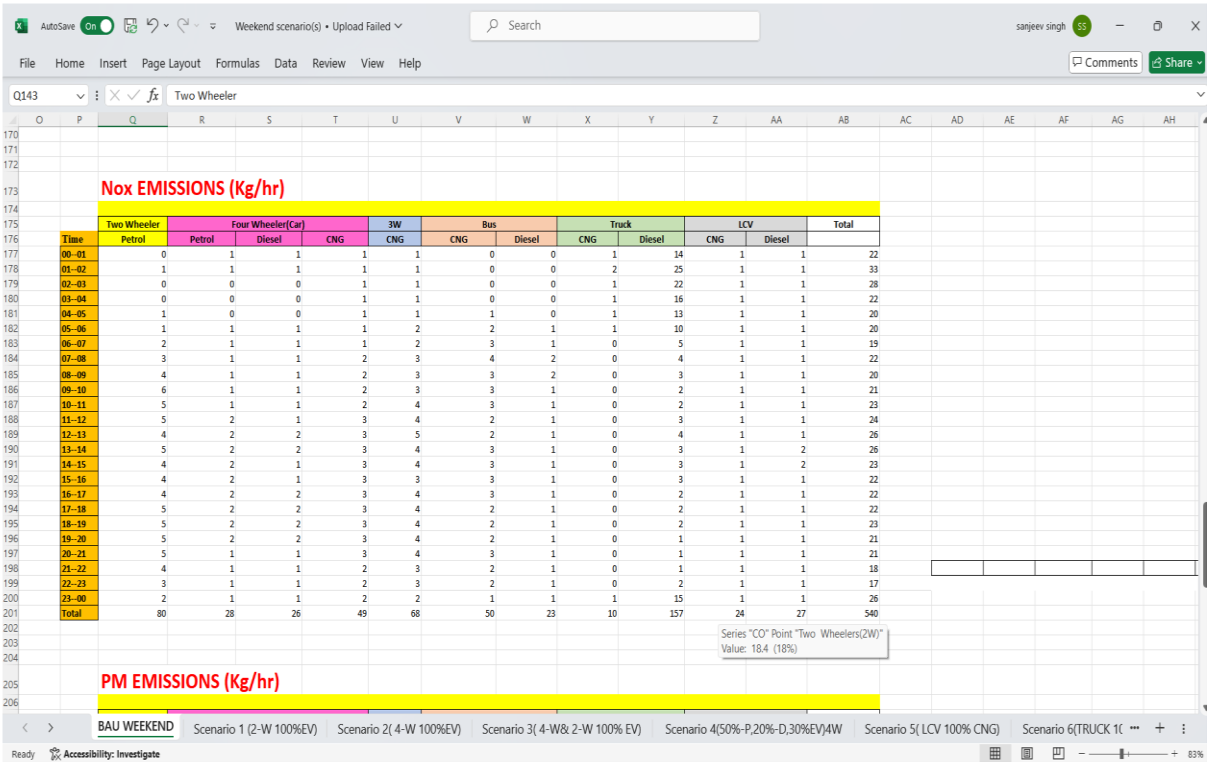
Fig 4.5: Calculation of Emission load of CO; Step:5



HC EMISSIONS (Kg/hr)

Time	Two Wheeler Petrol	Four Wheeler(Car) Petrol	Four Wheeler(Car) Diesel	Four Wheeler(Car) CNG	3W CNG	Bus CNG	Bus Diesel	Truck CNG	Truck Diesel	LCV CNG	LCV Diesel	Total
00--01	1	1	0	1	1	0	0	1	1	1	1	7
01--02	1	1	0	1	0	0	0	1	1	1	1	7
02--03	0	1	0	0	0	0	0	1	1	1	1	5
03--04	0	0	0	0	0	0	0	1	1	1	1	5
04--05	1	1	0	0	1	1	0	1	1	1	1	5
05--06	1	[illegible]	[illegible]	1	1	1	0	1	0	1	1	7
06--07	2	[illegible]	[illegible]	1	1	2	0	0	0	1	1	10
07--08	3	1	0	1	2	3	0	0	0	1	1	13
08--09	4	2	0	1	1	3	0	0	0	0	1	13
09--10	5	2	0	1	2	2	0	0	0	1	1	14
10--11	5	2	0	1	2	3	0	0	0	1	1	15
11--12	4	2	0	2	2	2	0	0	0	1	1	15
12--13	4	2	1	2	2	2	0	0	0	1	1	15
13--14	5	3	1	2	2	2	0	0	0	1	1	16
14--15	4	2	1	2	2	2	0	0	0	1	1	14
15--16	3	2	1	2	2	2	0	0	0	1	1	14
16--17	4	2	1	2	2	2	0	0	0	1	1	14
17--18	4	3	1	2	2	2	0	0	0	1	1	15
18--19	5	3	1	2	2	2	0	0	0	0	1	15
19--20	5	3	1	2	2	2	0	0	0	0	0	15
20--21	5	2	0	2	2	2	0	0	0	0	0	14
21--22	4	2	0	1	2	2	0	0	0	0	1	12
22--23	3	2	0	1	1	2	0	0	0	0	0	11
23--00	2	1	0	1	1	1	0	1	1	1	1	9
Total	75	41	9	30	35	43	1	8	7	14	17	280

Fig 4.6: Calculation of Emission load of HC; Step:6

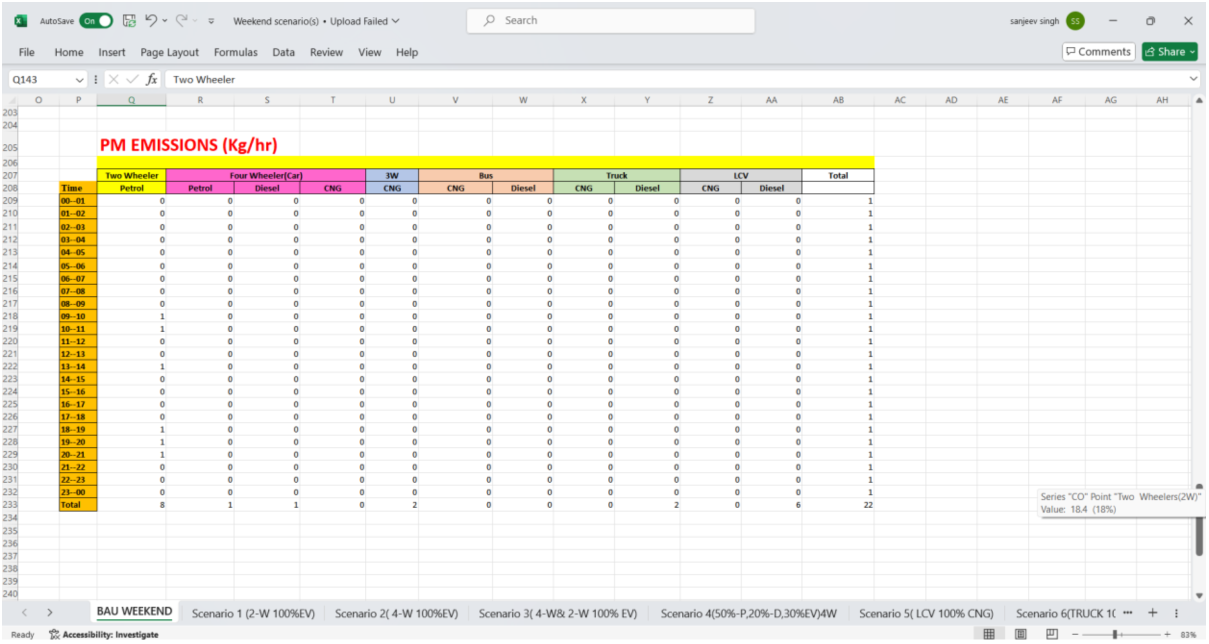


Nox EMISSIONS (Kg/hr)

Time	Two Wheeler Petrol	Four Wheeler(Car) Petrol	Four Wheeler(Car) Diesel	Four Wheeler(Car) CNG	3W CNG	Bus CNG	Bus Diesel	Truck CNG	Truck Diesel	LCV CNG	LCV Diesel	Total
00--01	0	1	1	1	1	0	0	1	14	1	1	22
01--02	1	1	1	1	1	0	0	2	25	1	1	33
02--03	0	0	0	1	1	0	0	1	22	1	1	28
03--04	0	0	0	1	1	0	0	1	16	1	1	22
04--05	1	0	0	1	1	1	0	1	13	1	1	20
05--06	1	1	1	1	2	2	1	1	10	1	1	20
06--07	2	1	1	1	2	3	1	0	5	1	1	19
07--08	3	1	1	2	3	4	2	0	4	1	1	22
08--09	4	1	1	2	3	3	2	0	3	1	1	20
09--10	6	1	1	2	3	3	1	0	2	1	1	21
10--11	5	1	1	2	4	3	1	0	2	1	1	23
11--12	5	2	1	3	4	2	1	0	3	1	1	24
12--13	4	2	2	3	5	2	1	0	4	1	1	26
13--14	5	2	2	3	4	3	1	0	3	1	2	26
14--15	4	2	1	3	4	3	1	0	3	1	2	23
15--16	4	2	1	3	3	3	1	0	3	1	1	22
16--17	4	2	2	3	4	3	1	0	2	1	1	22
17--18	5	2	2	3	4	2	1	0	2	1	1	22
18--19	5	2	2	3	4	2	1	0	2	1	1	23
19--20	5	2	2	3	4	2	1	0	1	1	1	21
20--21	5	1	1	3	4	3	1	0	1	1	1	21
21--22	4	1	1	2	3	2	1	0	1	1	1	18
22--23	3	1	1	2	3	2	1	0	2	1	1	17
23--00	2	1	1	2	2	1	1	1	15	1	1	26
Total	80	28	26	49	68	50	23	10	157	24	27	540

PM EMISSIONS (Kg/hr)

Fig 4.7: Calculation of Emission load of NOx; Step:7



PM EMISSIONS (Kg/hr)

Time	Two Wheeler Petrol	Four Wheeler(Car) Petrol	Four Wheeler(Car) Diesel	Four Wheeler(Car) CNG	3W CNG	Bus CNG	Bus Diesel	Truck CNG	Truck Diesel	LCV CNG	LCV Diesel	Total
00--01	0	0	0	0	0	0	0	0	0	0	0	1
01--02	0	0	0	0	0	0	0	0	0	0	0	1
02--03	0	0	0	0	0	0	0	0	0	0	0	1
03--04	0	0	0	0	0	0	0	0	0	0	0	1
04--05	0	0	0	0	0	0	0	0	0	0	0	1
05--06	0	0	0	0	0	0	0	0	0	0	0	1
06--07	0	0	0	0	0	0	0	0	0	0	0	1
07--08	0	0	0	0	0	0	0	0	0	0	0	1
08--09	0	0	0	0	0	0	0	0	0	0	0	1
09--10	1	0	0	0	0	0	0	0	0	0	0	1
10--11	1	0	0	0	0	0	0	0	0	0	0	1
11--12	0	0	0	0	0	0	0	0	0	0	0	1
12--13	0	0	0	0	0	0	0	0	0	0	0	1
13--14	1	0	0	0	0	0	0	0	0	0	0	1
14--15	0	0	0	0	0	0	0	0	0	0	0	1
15--16	0	0	0	0	0	0	0	0	0	0	0	1
16--17	0	0	0	0	0	0	0	0	0	0	0	1
17--18	0	0	0	0	0	0	0	0	0	0	0	1
18--19	1	0	0	0	0	0	0	0	0	0	0	1
19--20	1	0	0	0	0	0	0	0	0	0	0	1
20--21	1	0	0	0	0	0	0	0	0	0	0	1
21--22	0	0	0	0	0	0	0	0	0	0	0	1
22--23	0	0	0	0	0	0	0	0	0	0	0	1
23--00	0	0	0	0	0	0	0	0	0	0	0	1
Total	8	1	1	0	2	0	0	0	2	0	6	22

Fig 4.8: Calculation of Emission load of PM; Step:8

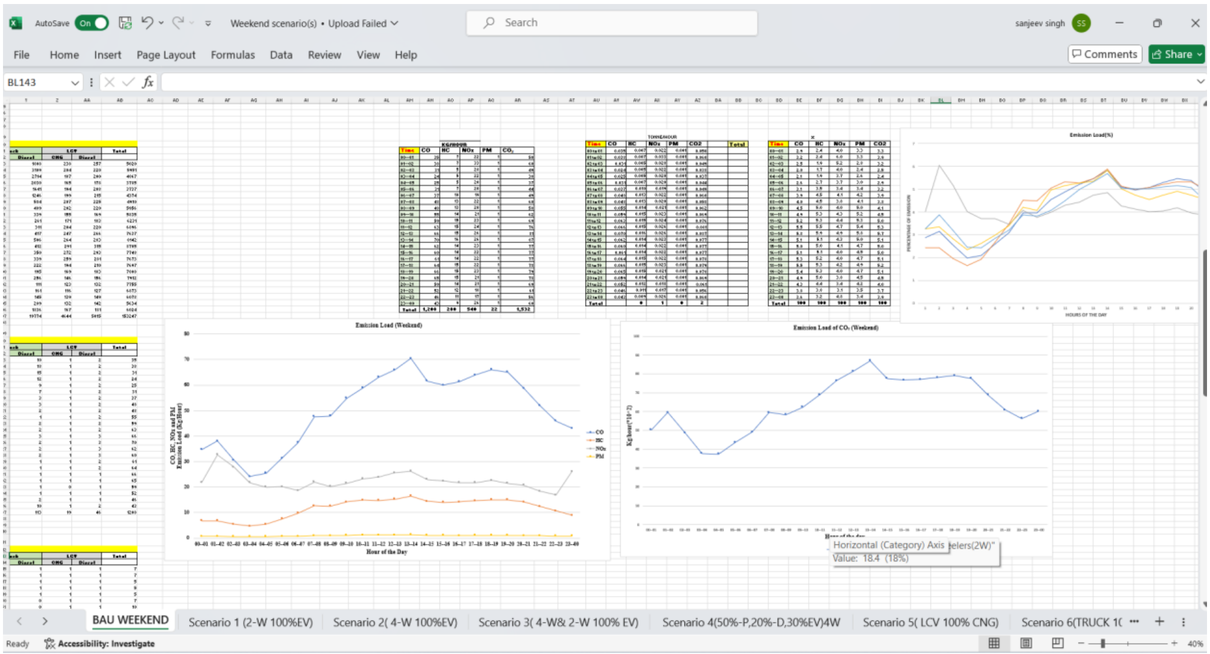


Fig 4.9: Plotting of graph with help of calculated load; Step:9

From fig:4.4 to fig:4.8 we have calculated the emission load for CO, HC, PM, NOx and CO_2 were estimated then these values were used for plotting graph for hourly variation and source wise bifurcation chart of the individual load. These steps have been repeated for all 8 scenarios to know their emission load. We have used MS excel sheet for calculation and plotting of graph.

CHAPTER 5

RESULTS AND DISCUSSION

According the various policy introduced to curb vehicular pollution the following scenarios were consider to estimate the vehicular emission at study area as per section 3.6.

1. Do-Nothing Scenario / BAU (Business as Usual Scenario)
2. 100% 2-Wheeler into Electric Vehicle Conversion Scenario
3. 100% 4-Wheeler into Electric Vehicle Conversion Scenario
4. 100% 4-Wheeler & 2 -Wheeler into Electric Vehicle Conversion Scenario
5. 50% Petrol, 20% Diesel and 30%- Electric Vehicle Four-Wheeler
6. 100% Light commercial vehicle into CNG Conversion Scenario
7. 100% Truck vehicle into CNG Conversion Scenario
8. Phasing out vehicles with age >15(petrol) years and >10(Diesel)
9. Introduction of BSVI emission standards in 2020

5.0 Emission Load Estimation

Vehicular emission loads (kg/day) corresponding to CO, HC, PM, NOx and CO_2 were estimated from all categories of the vehicles for both the seasons for CRRI traffic intersections. The emission loads were estimated using emission factors (CPCB/ARAI), traffic volume count (vehicle type) vintage of vehicle etc. The detailed methodology for estimation of emission loads has been provided in Chapter 3.

5.1 Do-Nothing Scenario / BAU (Business as Usual Scenario)

This scenario assumes that there is no change in emission factors and no policy has been introduce to curb vehicular pollution and the pollution keeps on rising with increase in growth of the vehicle population here the vehicle population has been estimated keep COVID period into account and near possible estimation has been done using old data. Estimated Emission Load for BAU (Business as Usual Scenario) during Weekend and Weekday at CRRI Traffic Intersection has been presented in Table 4.1. Hourly variation of the load has been depicted in the fig 4.1, fig 4.2, fig 4.3 and fig 4.4. Percentage distribution of CO, HC, PM, NOx and CO_2 according to vehicle type were shown in fig 4.5 to fig 4.14.

Table 5.1: Estimated Vehicular Emission Load during Weekend and Weekday at CRRI Traffic Intersection BAU (Business as Usual Scenario).

Time	Emission Load (kg)									
	CO		HC		Nox		PM		CO_2	
	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY	WEEKEND	WEEKDAY
00--01	35	34	7	6	22	24	1	1	50	50
01--02	38	26	7	5	33	23	1	1	60	40
02--03	31	19	5	4	28	18	1	0	49	30
03--04	24	19	5	4	22	18	1	0	38	30
04--05	25	19	5	4	20	15	1	0	37	28
05--06	31	27	7	8	20	18	1	1	44	37
06--07	37	40	10	12	19	21	1	1	49	51
07--08	48	68	13	17	22	26	1	1	60	84
08--09	48	78	13	19	20	27	1	1	58	88
09--10	55	95	14	23	21	33	1	2	62	103
10--11	59	96	15	23	23	34	1	2	69	106
11--12	63	90	15	21	24	36	1	2	76	108
12--13	66	81	15	20	26	36	1	2	81	97
13--14	70	79	16	19	26	33	1	2	87	94
14--15	62	75	14	18	23	32	1	2	77	92
15--16	60	73	14	18	22	31	1	1	77	90
16--17	61	75	14	18	22	29	1	1	77	89
17--18	64	91	15	21	22	31	1	2	78	103
18--19	66	103	15	26	23	35	1	2	79	105
19--20	65	87	15	21	21	30	1	2	78	90
20--21	59	74	14	19	21	26	1	2	69	77
21--22	52	61	12	16	18	23	1	1	61	68
22--23	46	46	11	12	17	19	1	1	56	54
23--00	43	43	9	11	26	27	1	1	60	58
Total	1208	1497	280	363	540	644	22	29	1532	1773

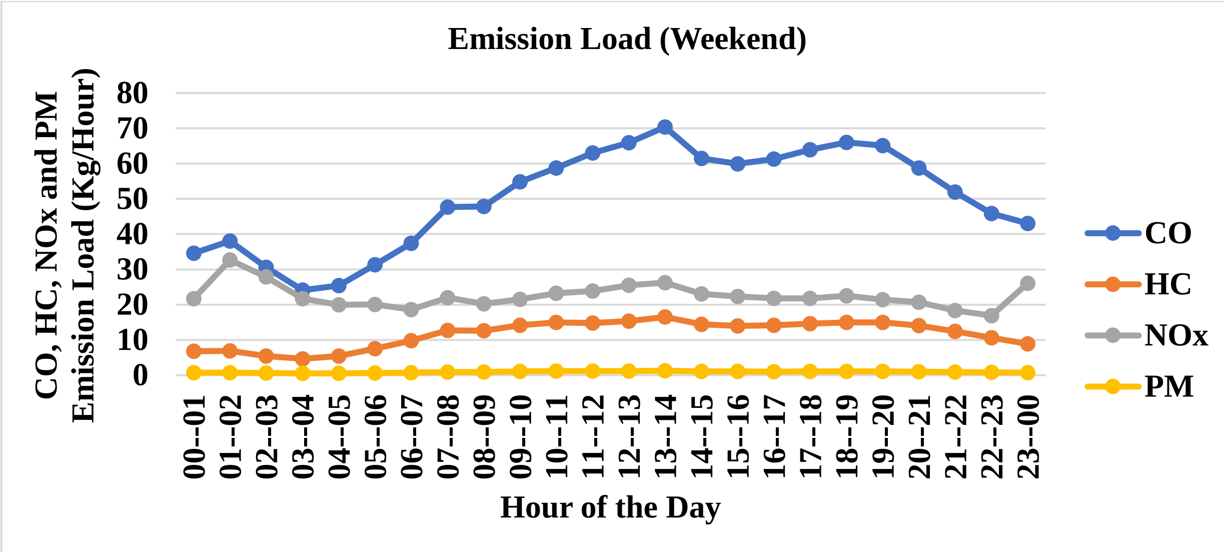


Fig. 5.1: Hourly variation of emission load weekend.

Fig. 5.1: Shows hourly variation in emission load during weekend where Y-axis represents emission load CO, HC, NOx and PM (Carbon monoxide, hydrocarbon, oxides of nitrogen and particulate matter. Highest emission load observed for CO followed by HC then NOx and then PM. Peak conc. is observed at 1-2pm and evening at 6-7pm.

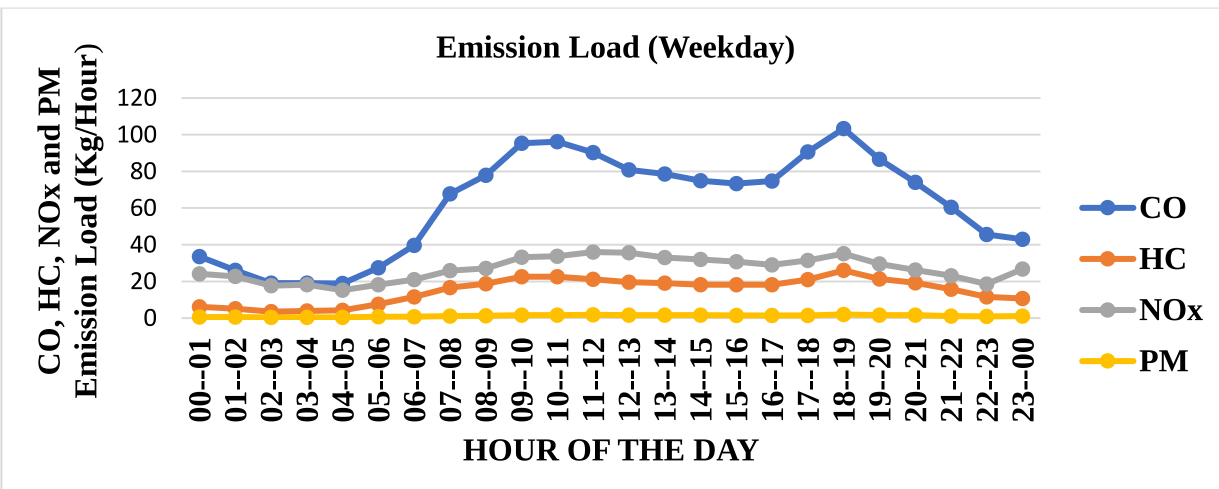


Fig. 5.2: Hourly variation of emission load weekday.

Fig. 5.2: Shows hourly variation in emission load during weekday where Y-axis represents emission load CO, HC, NOx and PM (Carbon monoxide, hydrocarbon, oxides of nitrogen and particulate matter. Highest emission load observed for CO followed by HC then NOx and then PM. Peak conc. is observed at 10-12 am and evening at 6-8pm.

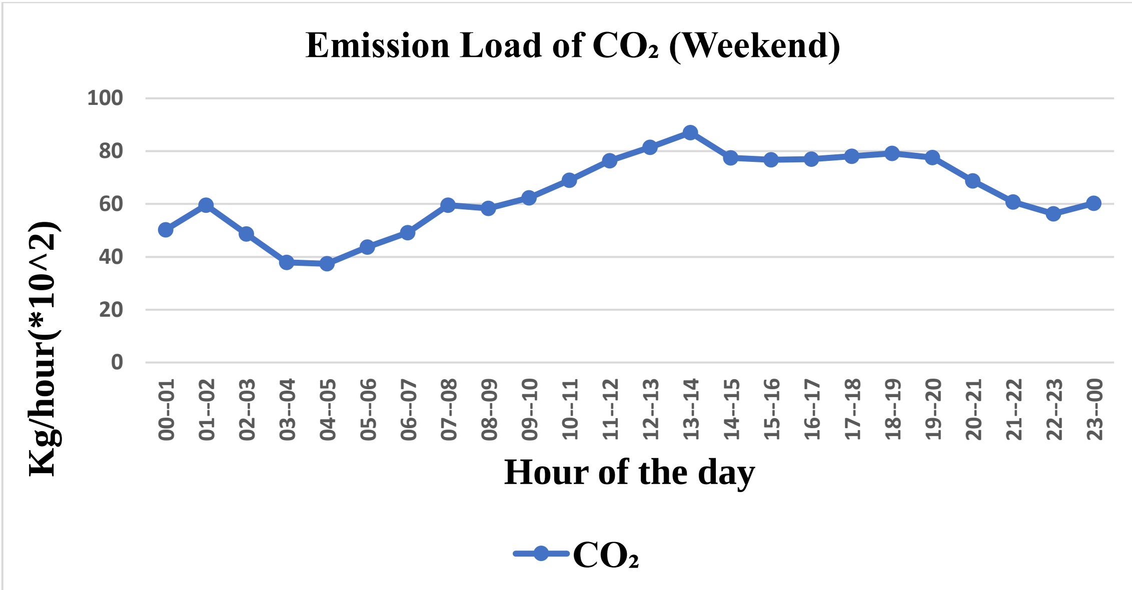


Fig. 5.3: Hourly variation of emission load CO_2 weekend.

Fig. 5.3: Shows hourly variation in emission load during weekend where Y-axis represents emission load of CO_2 (Carbon dioxide). Highest emission load for CO is observed at 1-2 pm and evening at 6-8pm.

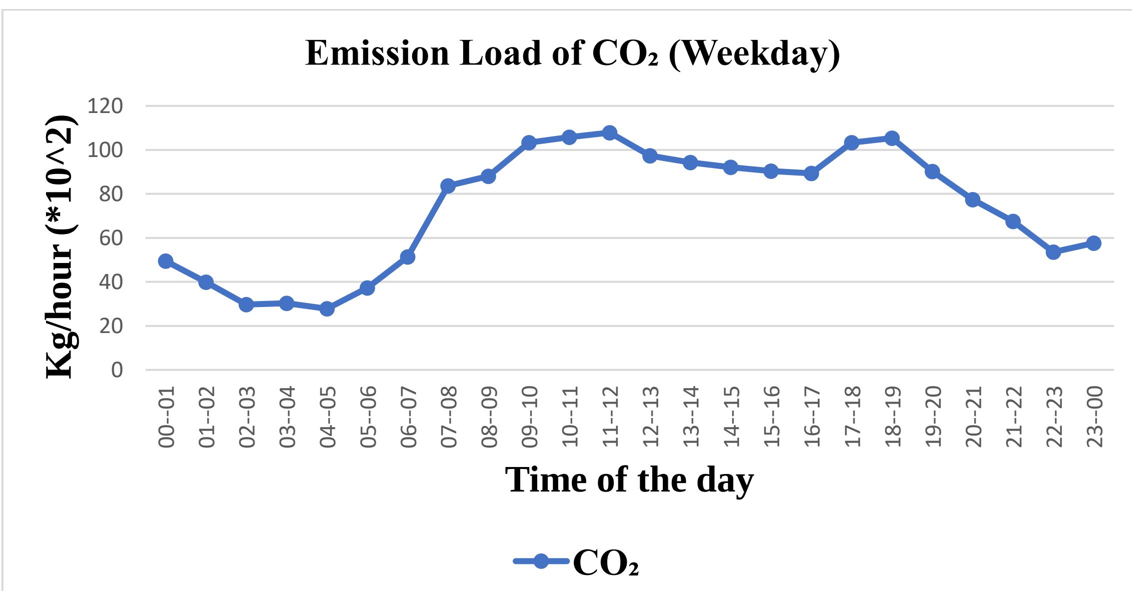


Fig. 5.4: Hourly variation of emission load CO_2 weekday.

Fig. 5.4: Shows hourly variation in emission load during weekend where Y-axis represents emission load of CO_2 (Carbon dioxide). Highest emission load for CO is observed at 10-12 am and evening at 6-8pm.

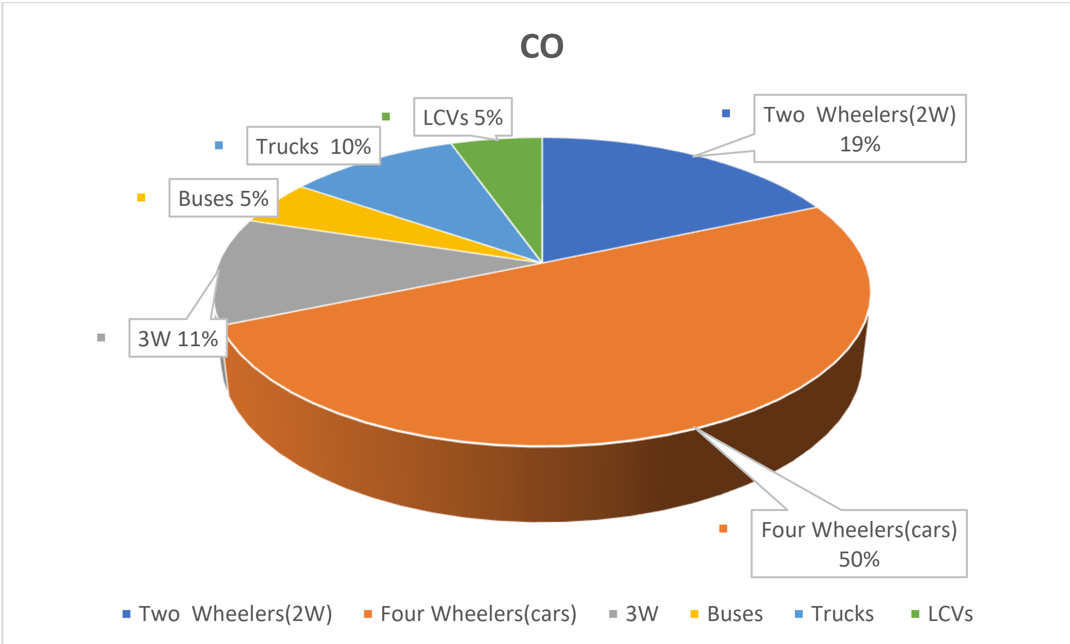


Fig. 5.5: CO Source- wise bifurcation-CRRI (weekend)

In fig 5.5 it shows that major contributor of CO is four wheelers in weekend of about 50%, followed by 2 wheelers then 3W, Truck and buses and LCVs.

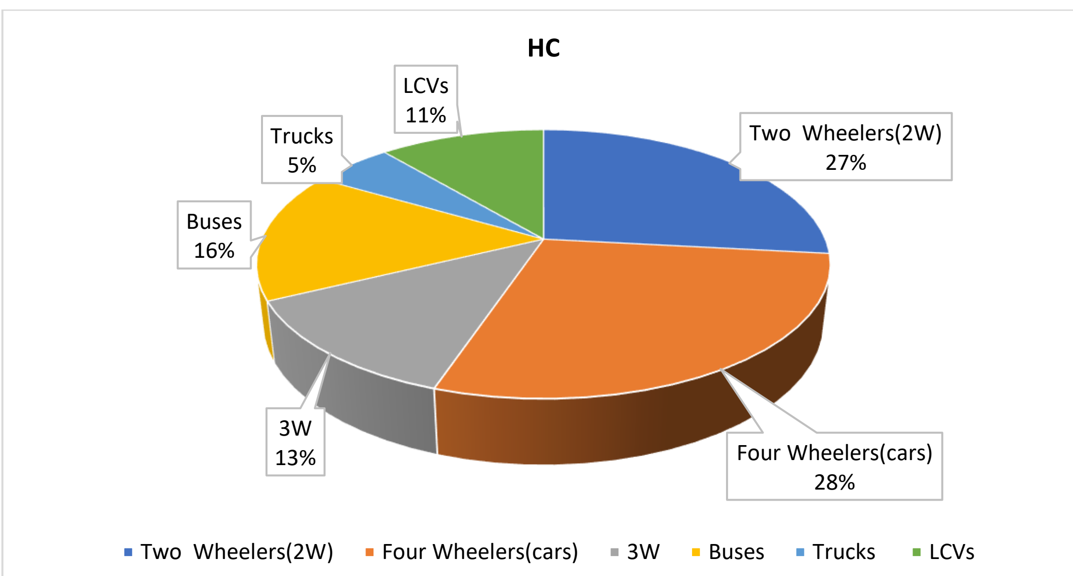


Fig. 5.6: HC Source- wise bifurcation-CRRI (weekend)

In fig 5.6 it shows that major contributor of HC is four wheelers in weekend of about 28% followed by 2 wheelers at 27%. then buses, 3W, LCVs and then Truck.

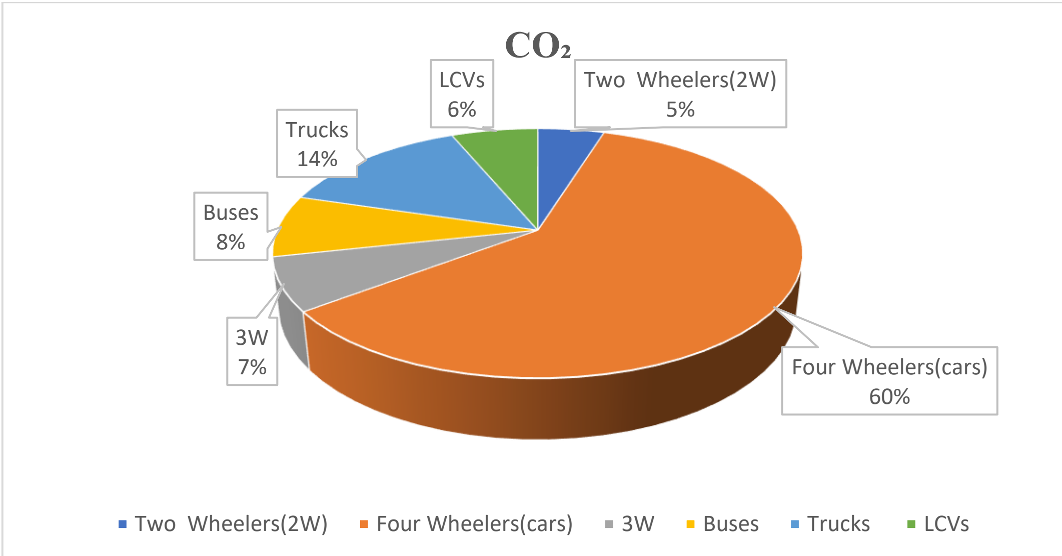


Fig. 5.7: CO_2 Source- wise bifurcation-CRRI (weekend)

In fig 5.7 it shows that major contributor of CO_2 is four wheelers in weekend of about 60% followed by Trucks at 14%, buses, 3w then LCVs.

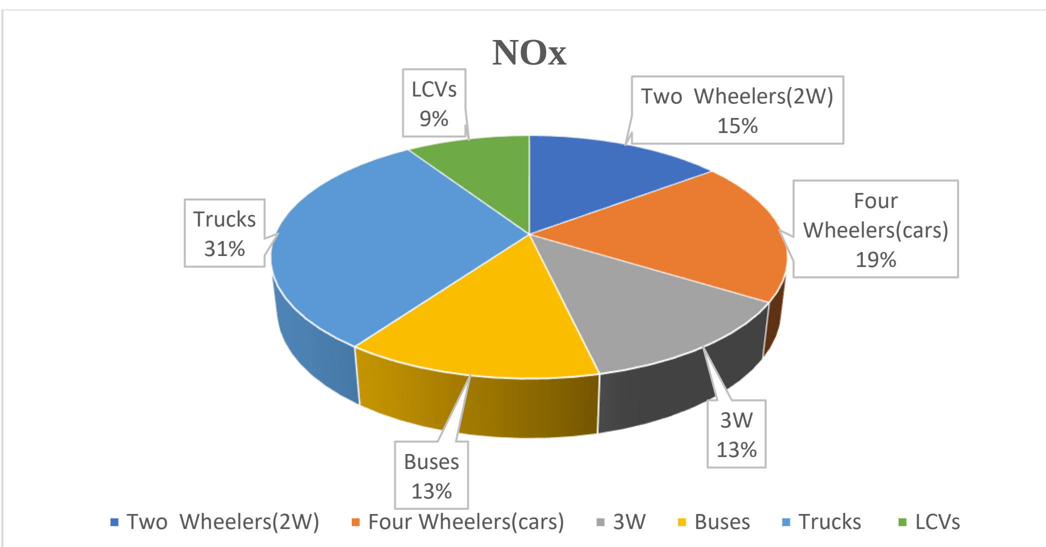


Fig. 5.8 NOx Source- wise bifurcation-CRRI (weekend)

In fig 5.8 it shows that major contributor of NOx is four wheelers in weekend of about 19% followed by 2 wheelers at 15%.

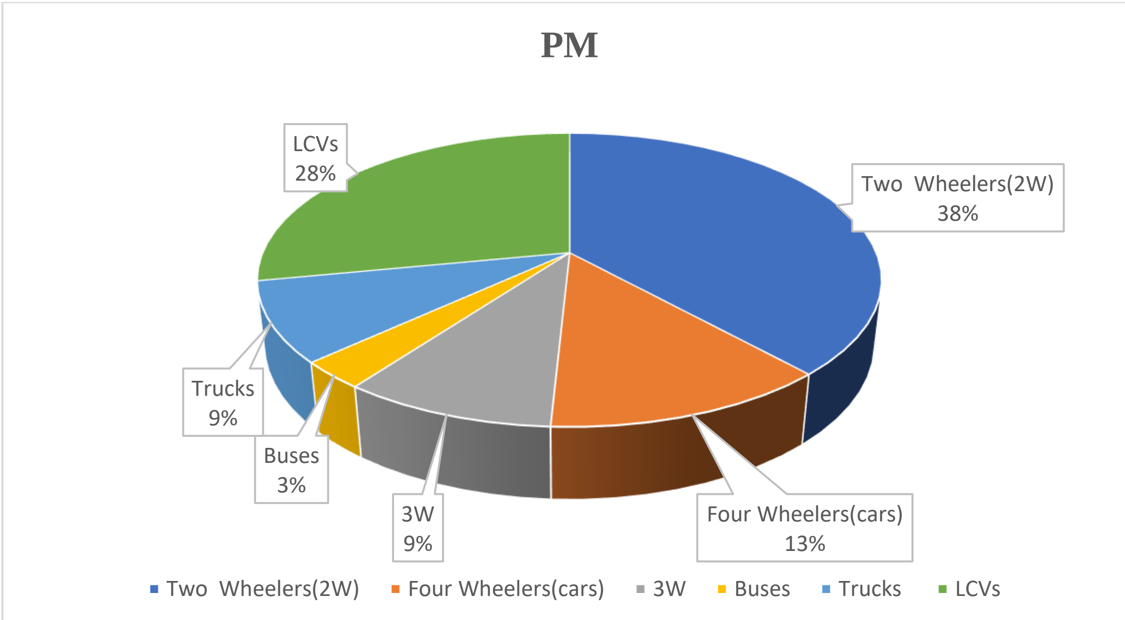


Fig. 5.9 PM Source- wise bifurcation-CRRI (weekend).

In fig 5.9 it shows that major contributor of PM is 2 Wheelers in weekend of about 38% followed by Four wheelers at 13% then LCVs, Trucks, 3W and buses.

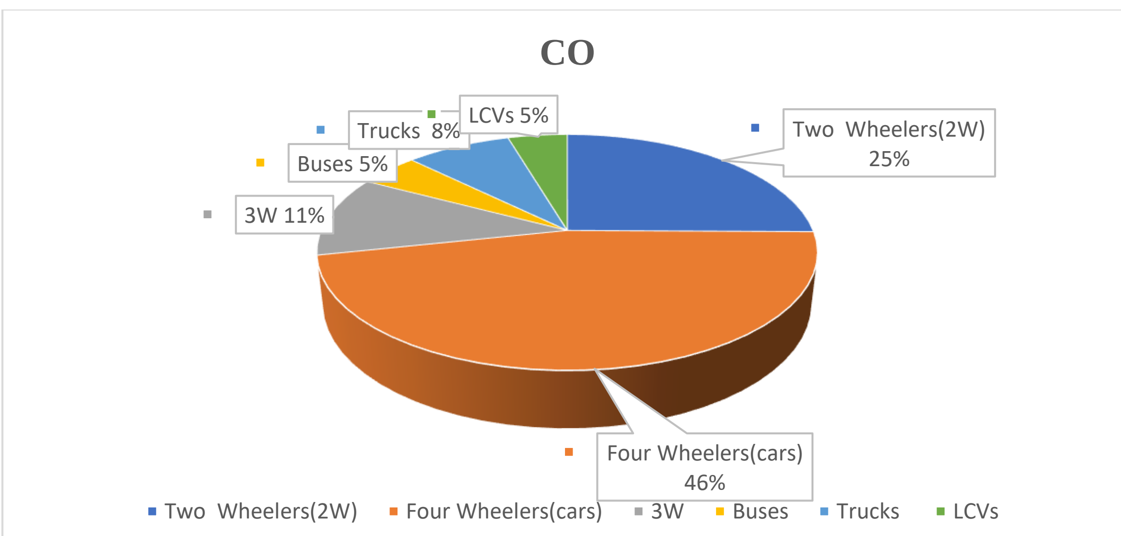


Fig. 5.10: CO Source- wise bifurcation-CRRI (weekday)

In fig 5.10 it shows that major contributor of CO is four wheelers in weekday of about 46%, followed by 2 wheelers at 25% then 3W, trucks, buses and LCVs.

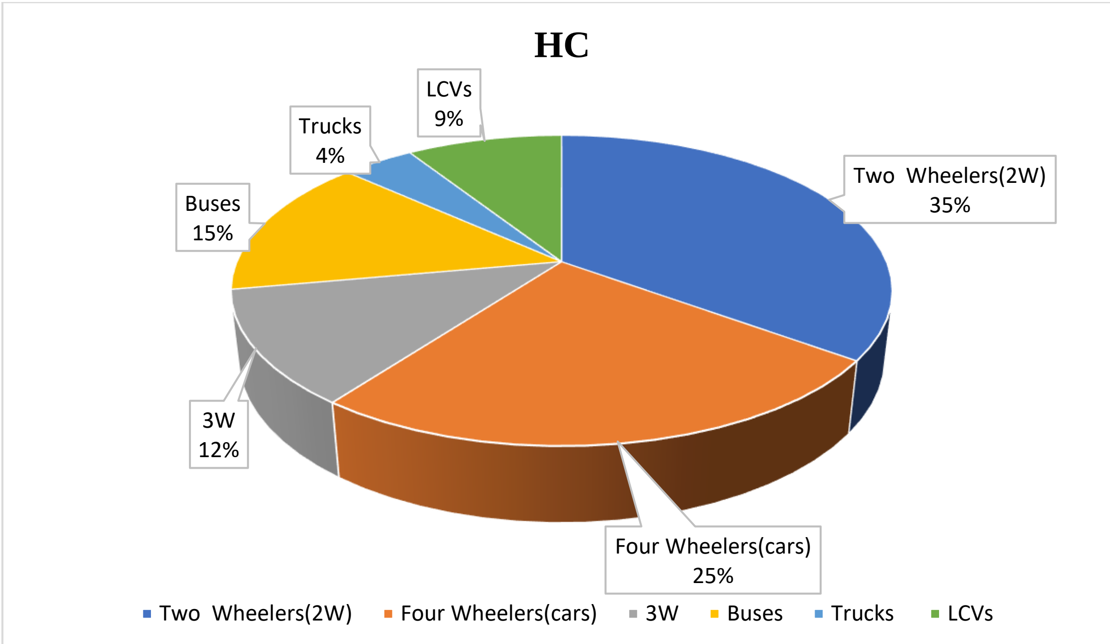


Fig. 5.11: HC Source- wise bifurcation-CRRI (weekday).

In fig 5.11 it shows that major contributor of HC is 2 wheelers in weekday of about 35% followed by four wheelers at 25% then 3W, buses, LCVs and then truck.

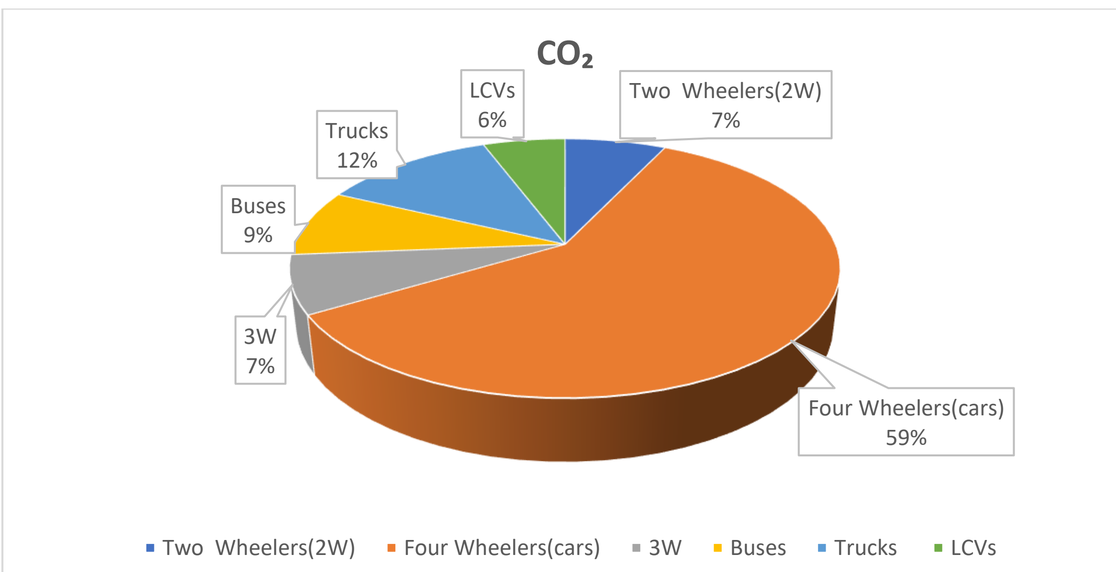


Fig. 5.12: CO_2 Source- wise bifurcation-CRRI (weekday)

In fig 5.12 it shows that major contributor of CO_2 is 4 wheelers in weekday of about 59% followed by Trucks at 12% then buses, 2w, 3w and LCVs.

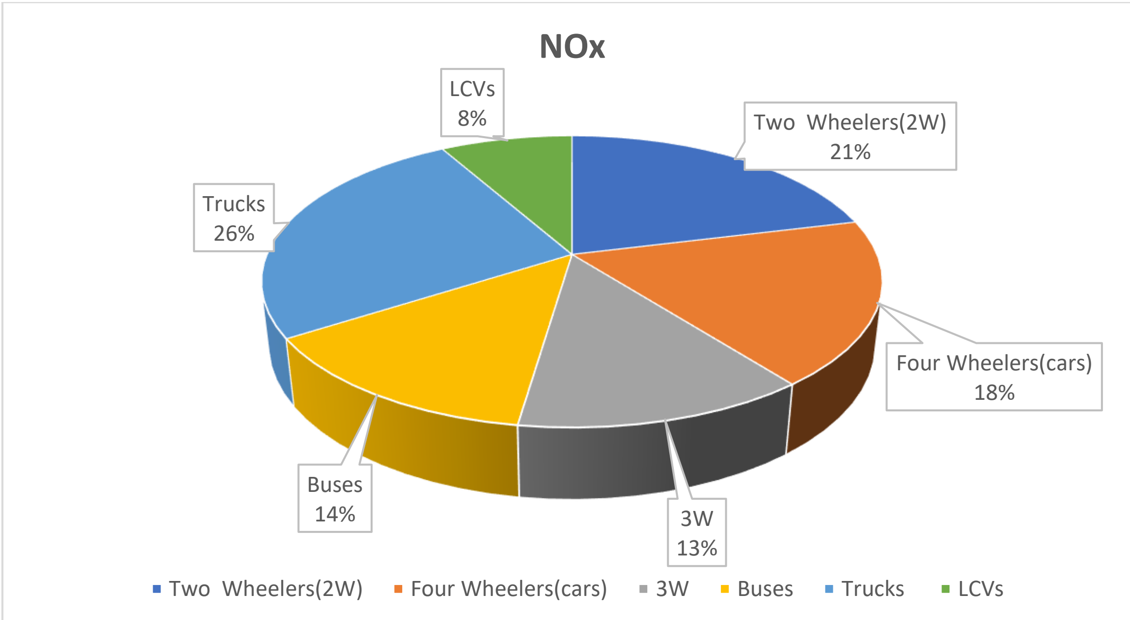


Fig. 5.13: NOx Source- wise bifurcation-CRRI (weekday)

In fig 5.13 it shows that major contributor of NOx is 2 wheelers in weekday of about 21% followed by Trucks at 26% followed by buses, 3w and LCVs.

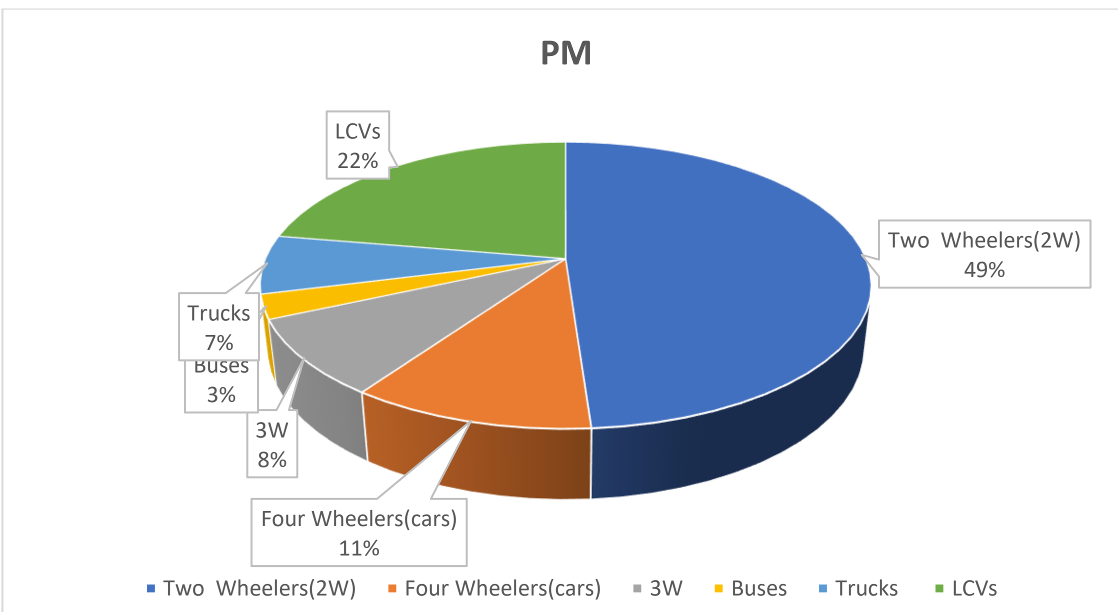


Fig. 5.14: PM Source- wise bifurcation-CRRI (weekday)

In fig 5.14 it shows that major contributor of PM is 2 wheelers in weekday of about 49% followed by LCV at 22% then Four-wheeler, 3w, trucks and then buses.

5.2 100% 2-Wheeler into Electric Vehicle Conversion Scenario - Scenario 1.

In this scenario, it is assumed that all two-wheelers are converted to electric vehicles, resulting in zero emission factors for these vehicles due to the absence of tailpipe emissions. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.15 and fig 5.17 and for CO_2 conc. it is shown in fig 5.16 and 5.18. In fig 5.19 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 1 has been shown. Converting 2-W into electric would have positive effect in terms of curbing air pollution.

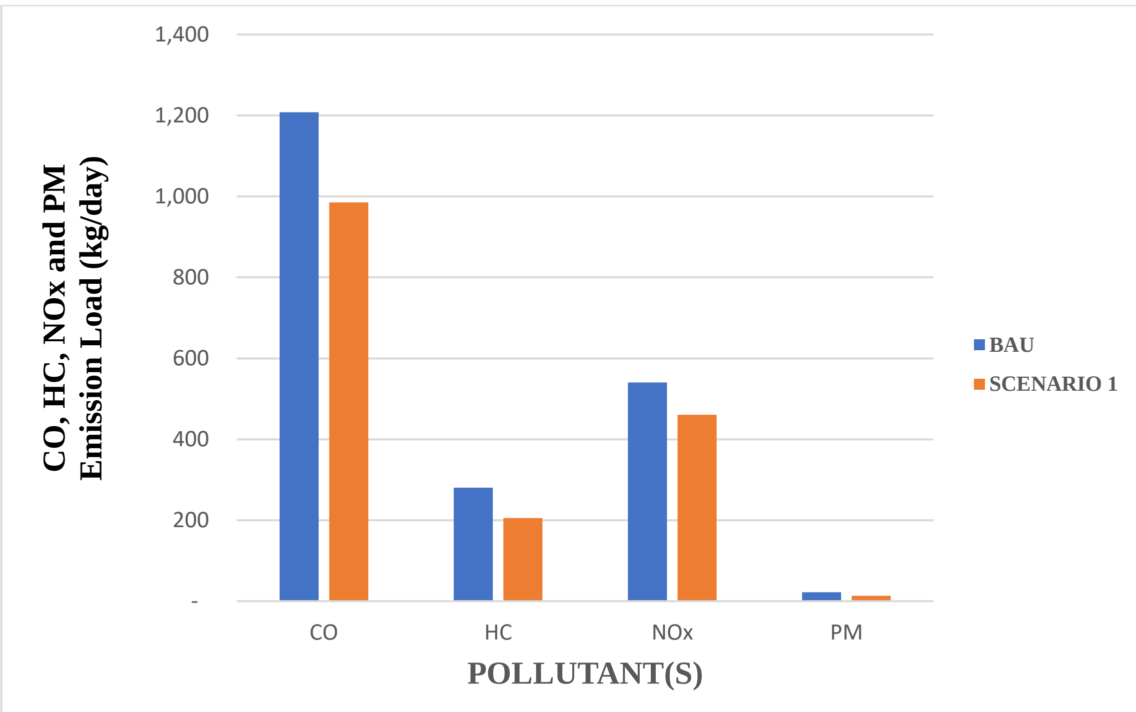


Fig. 5.15: Change in conc. of pollutants Weekend in scenario 1.

Fig 5.15 shows that in scenario 1 (weekend) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to all 2-wheeler into electric would reduce tailpipe emission significantly.

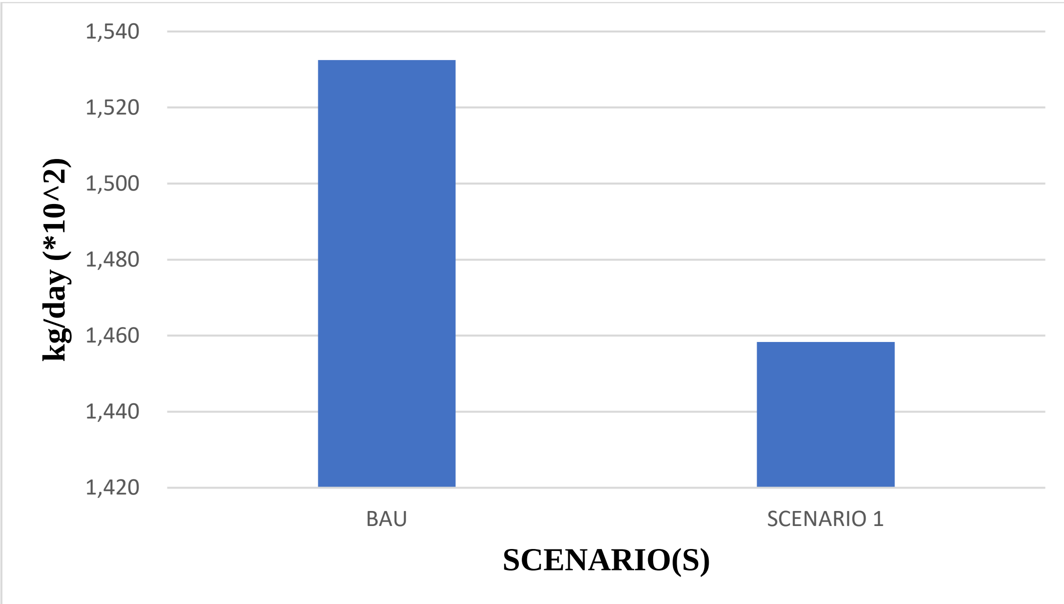


Fig. 5.16: Change in conc. of CO_2 pollutant Weekend in scenario 1.

Fig 5.16 shows that in scenario 1 (weekend) the emission load value of CO_2 decrease strikingly which means converting to all 2-wheeler into electric would reduce tailpipe emission significantly.

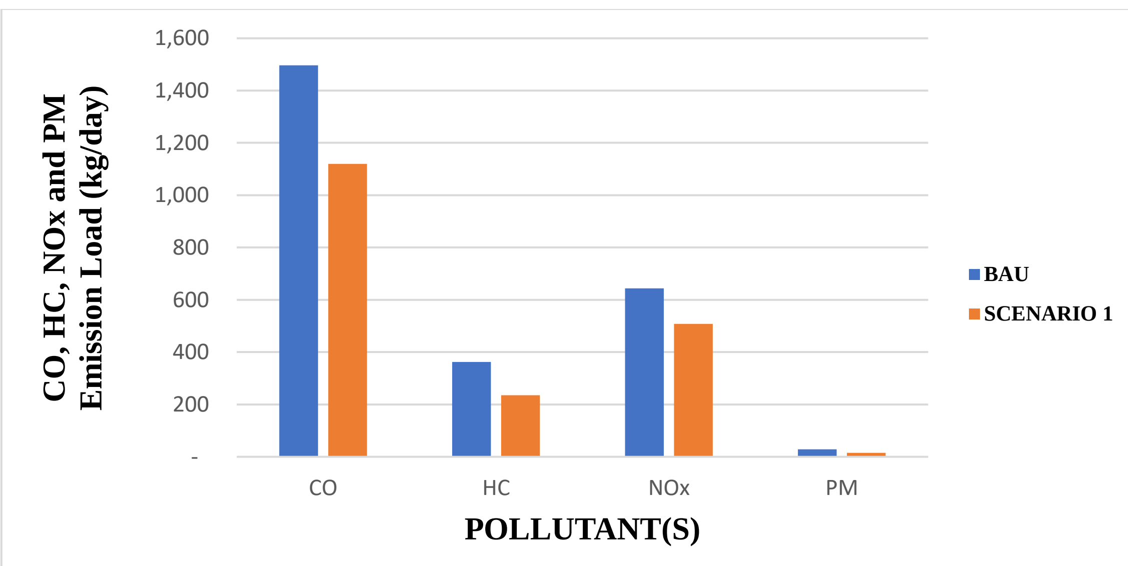


Fig. 5.17: Change in conc. of pollutants Weekday in scenario 1.

Fig 5.17 shows that in scenario 1 (weekday) the emission load value decrease strikingly which means converting to all 2-wheeler into electric would reduce tailpipe emission significantly.

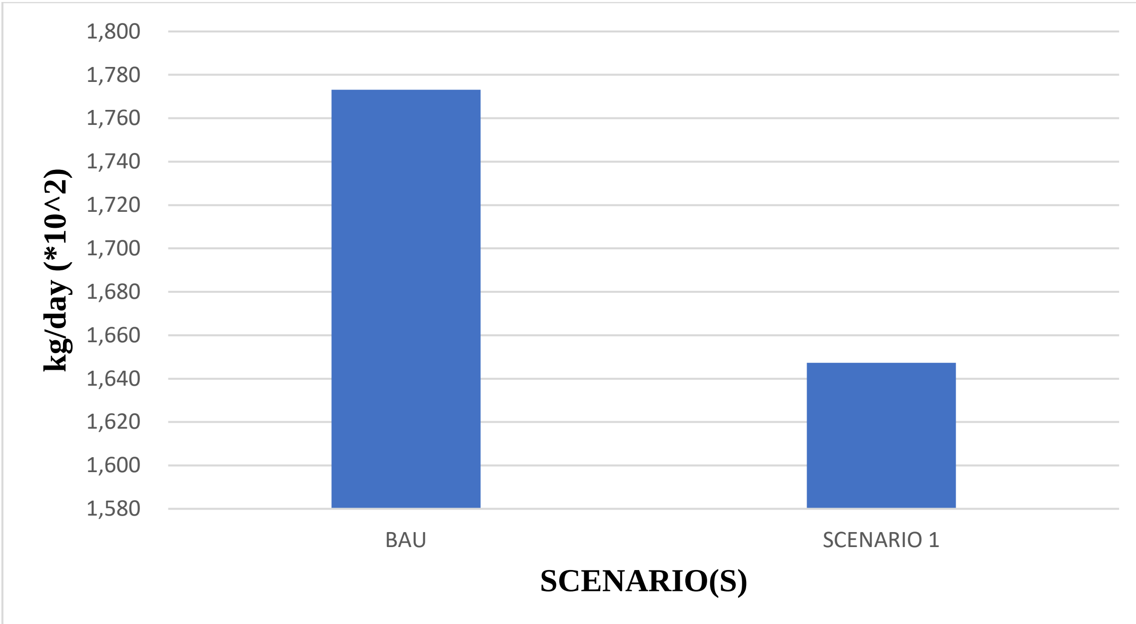


Fig. 5.18: Change in conc. of CO_2 pollutant Weekday in scenario 1.

Fig 5.18 shows that in scenario 1 (weekday) the emission load value of CO_2 decrease strikingly which means converting to all 2-wheeler into electric would reduce tailpipe emission significantly and in fig.5.19 it shows percentage reduction in emission compared it to BAU scenario.

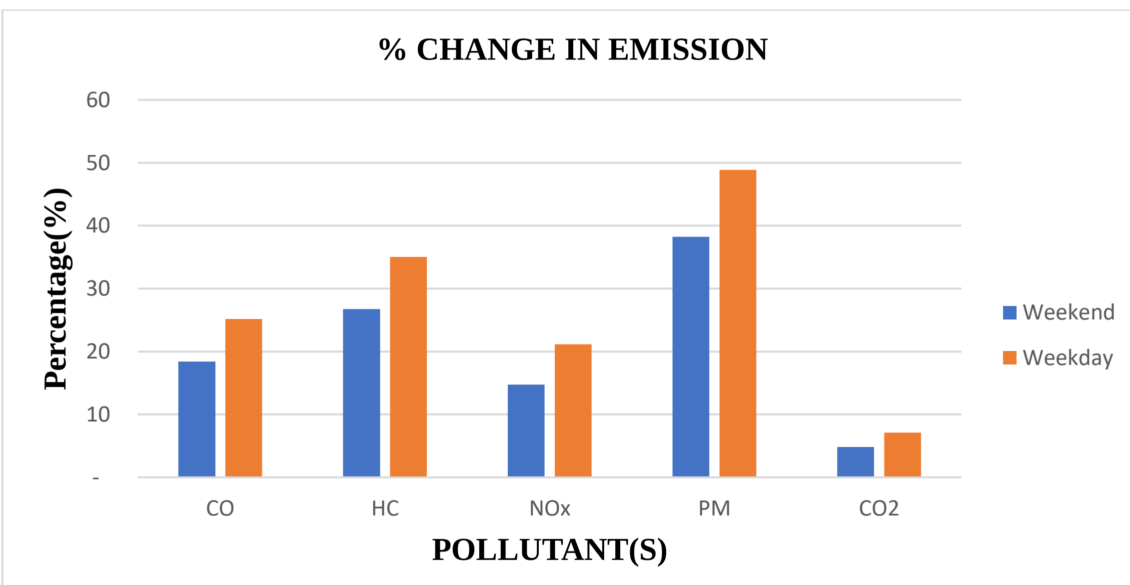


Fig. 5.19: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 1.

5.3 100% 4-Wheeler into Electric Vehicle Conversion Scenario - Scenario 2.

In this scenario, it is assumed that all Four-wheelers are converted to electric vehicles, resulting in zero emission factors for these vehicles due to the absence of tailpipe emissions. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.20 and fig 5.22 and for CO_2 conc. it is shown in fig 5.21 and 5.23. In fig 5.24 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 2 has been shown. Converting all 4-W into electric would have positive effect in terms of curbing air pollution.

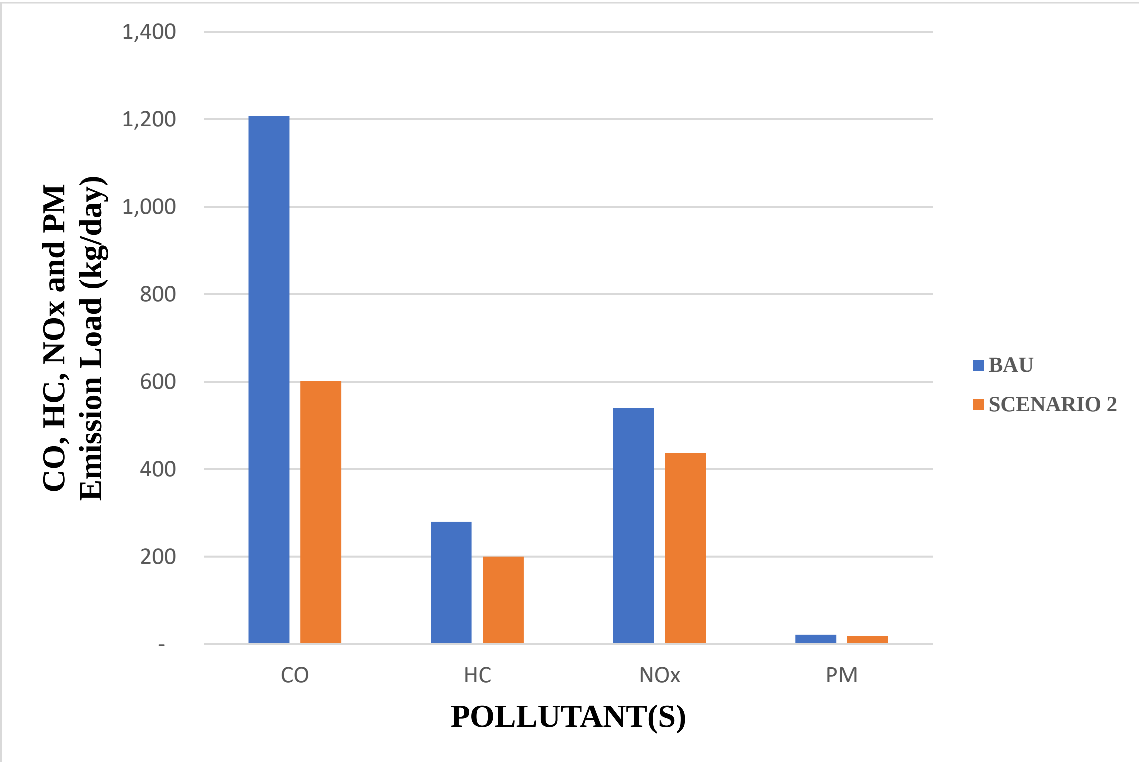


Fig. 5.20: Change in conc. of pollutants Weekend in scenario 2.

Fig 5.20 shows that in scenario 2 (weekend) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to all Four-wheeler into electric would reduce tailpipe emission significantly.

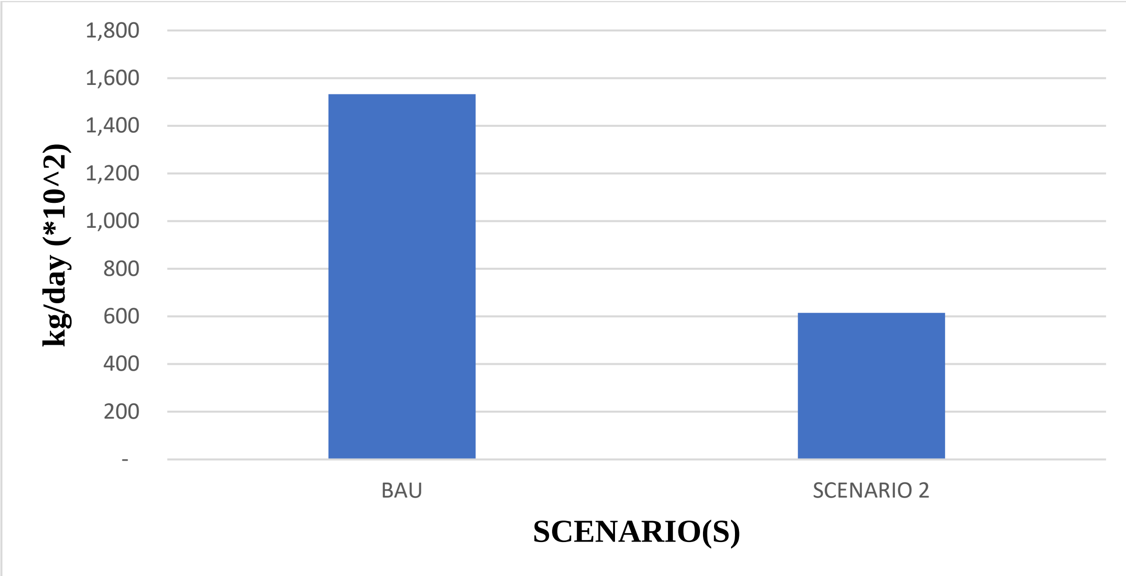


Fig. 5.21: Change in conc. of CO_2 pollutant Weekend in scenario 2.

Fig 5.21 shows that in scenario 2 (weekend) the emission load value of CO_2 decrease strikingly which means converting to all Four-wheeler into electric would reduce tailpipe emission significantly.

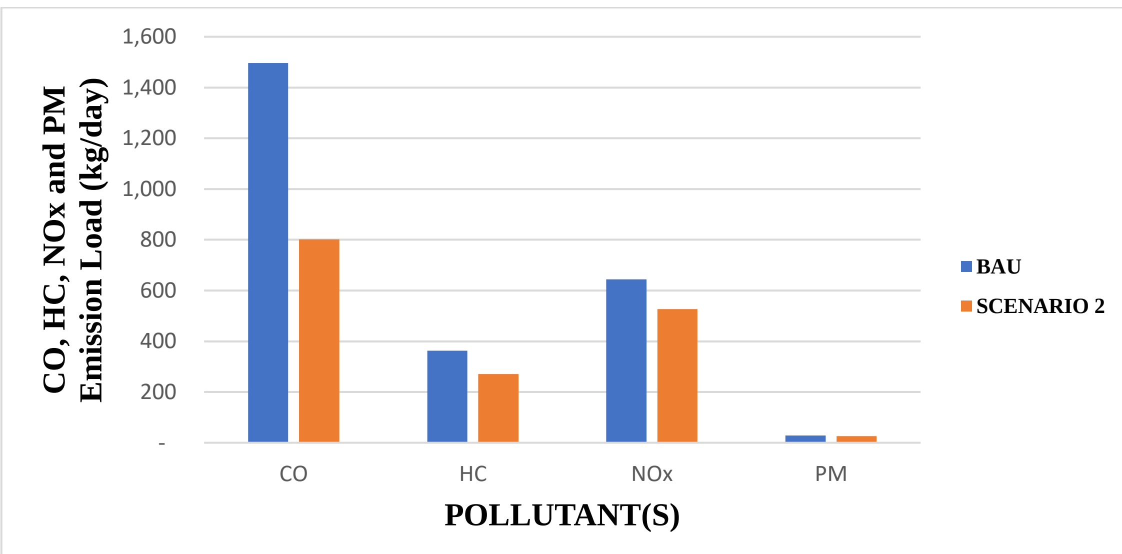


Fig. 5.22: Change in conc. of pollutants Weekday in scenario 2.

Fig 5.22 shows that in scenario 2 weekday all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to all Four-wheeler into electric would reduce tailpipe emission significantly.

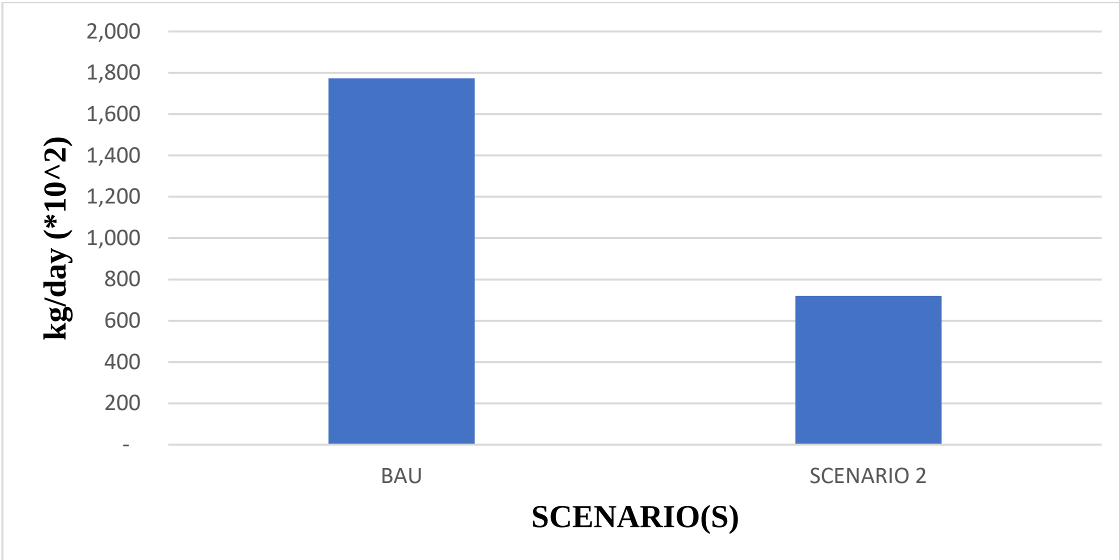


Fig. 5.23: Change in conc. of CO_2 pollutant Weekday in scenario 2.

Fig 5.23 shows that in scenario 2 (weekday) the emission load value of CO_2 decrease strikingly which means converting to all Four-wheeler into electric would reduce tailpipe emission significantly. Fig.5.24 It shows percentage reduction in emission compared it to BAU scenario.

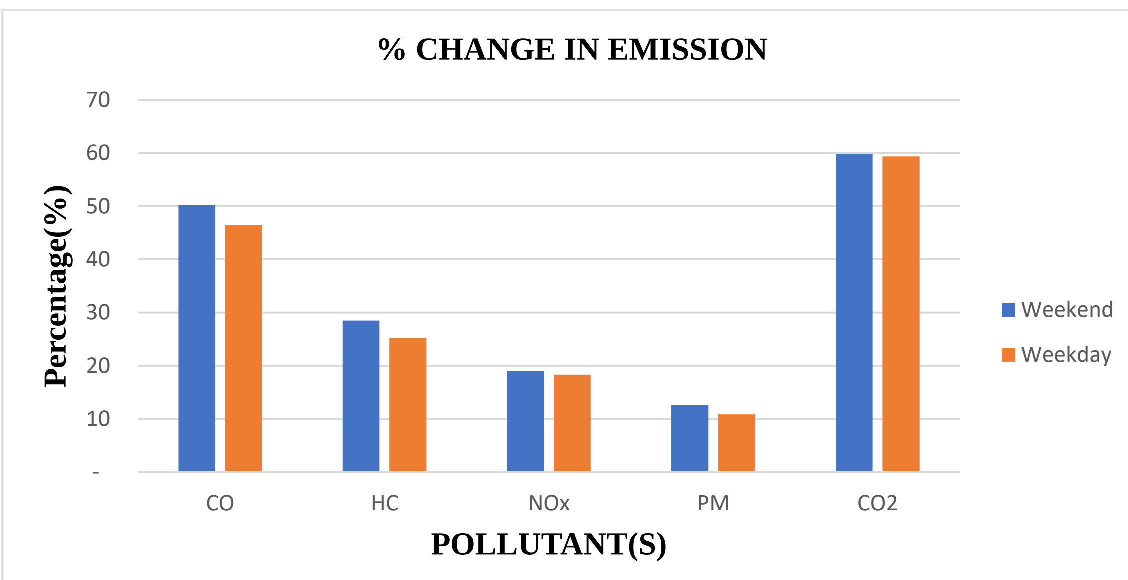


Fig. 5.24: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 2.

5.4 100% 4-Wheeler & 2 -Wheeler into Electric Vehicle Conversion Scenario - Scenario 3.

In this scenario, it is assumed that all 4-Wheeler & 2 -Wheeler are converted to electric vehicles, resulting in zero emission factors for these vehicles due to the absence of tailpipe emissions. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.25 and fig 5.27 and for CO_2 conc. it is shown in fig 5.26 and 5.28. In fig 5.29 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 3 has been shown. Converting all 4-Wheeler & 2 -Wheeler into Electric Vehicle into electric would have positive effect in terms of curbing air pollution.

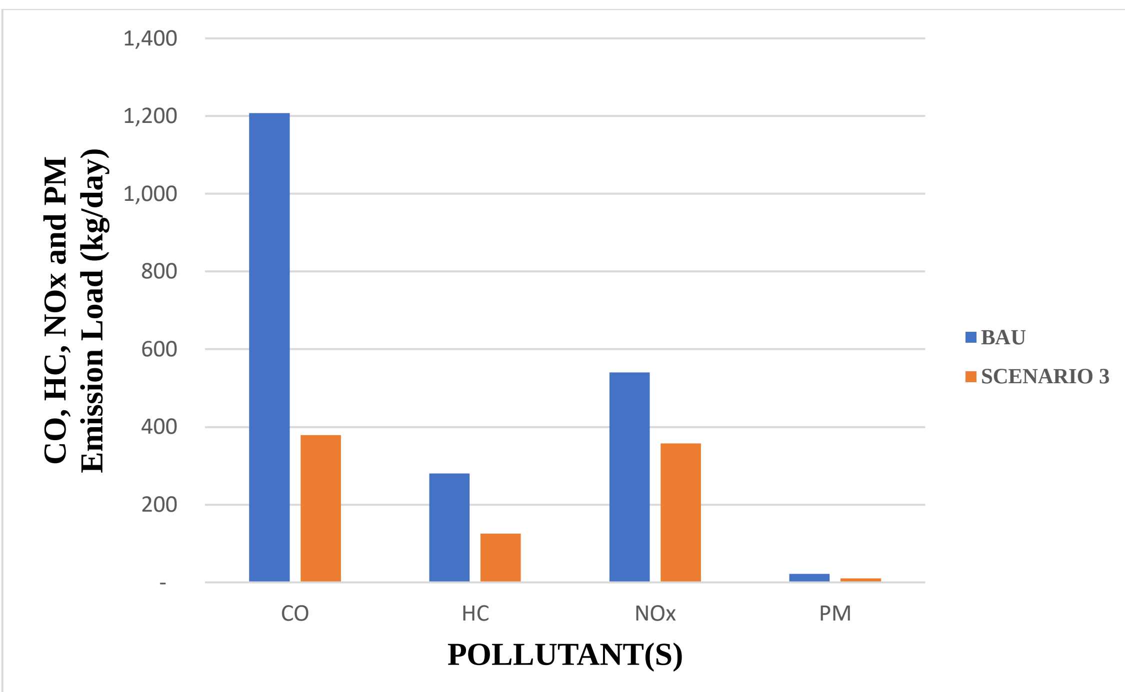


Fig. 5.25: Change in conc. of pollutant Weekend in scenario 3.

Fig 5.25 shows that in scenario 3 (weekend) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to all 4-Wheeler & 2 -Wheeler into Electric Vehicle would reduce tailpipe emission significantly.

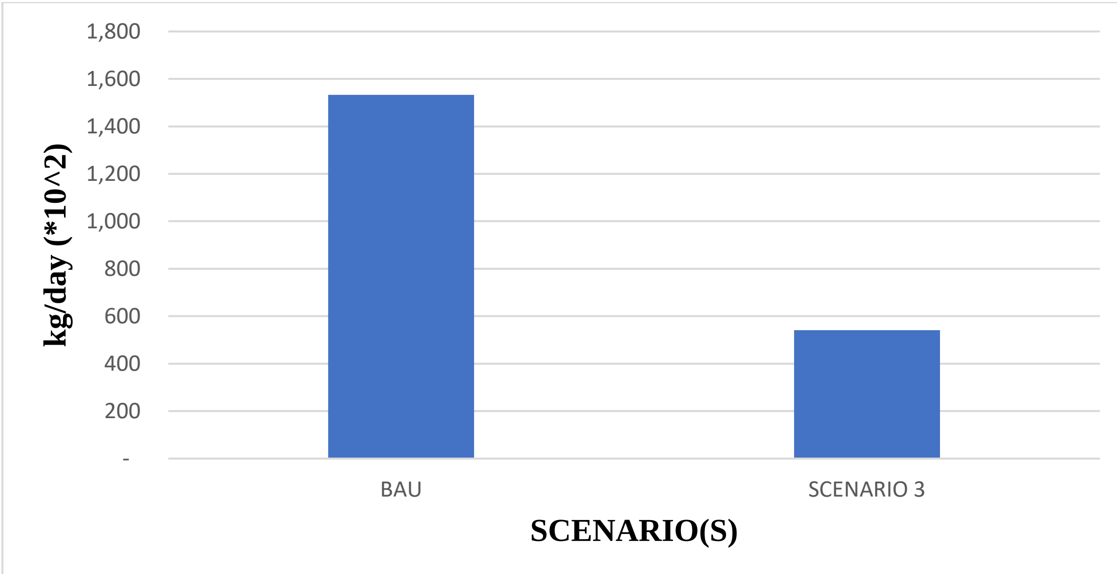


Fig. 5.26: Change in conc. of CO_2 pollutant Weekend in scenario 3.

Fig 5.26 shows that in scenario 3 (weekend) the emission load value of CO_2 decrease strikingly which means converting to all 4-Wheeler & 2 -Wheeler into Electric Vehicle would reduce tailpipe emission significantly.

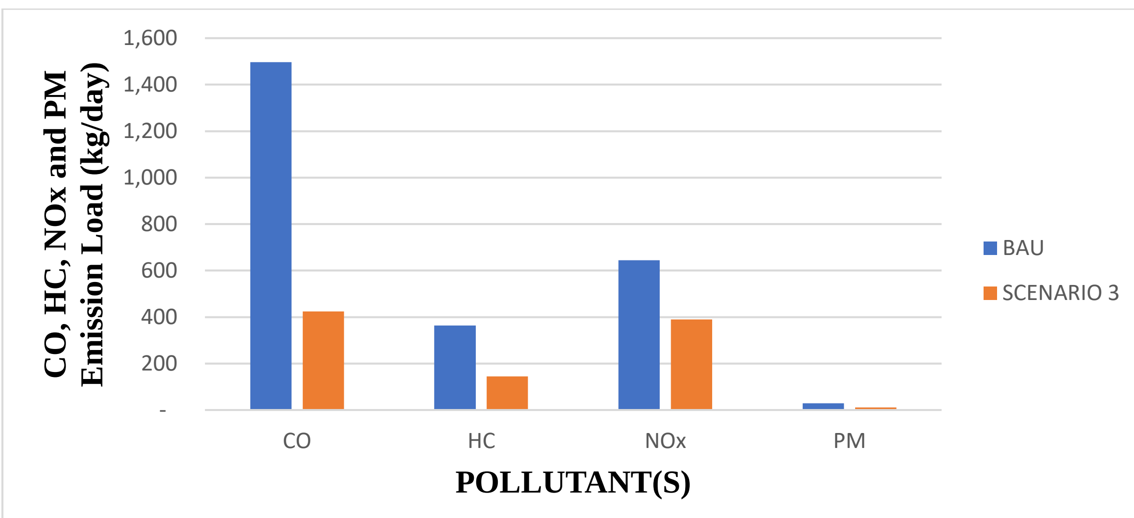


Fig. 5.27: Change in conc. of pollutant Weekday in scenario 3.

Fig 5.27 shows that in scenario 3 (weekday) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to all 4-Wheeler & 2 -Wheeler into Electric Vehicle would reduce tailpipe emission significantly.

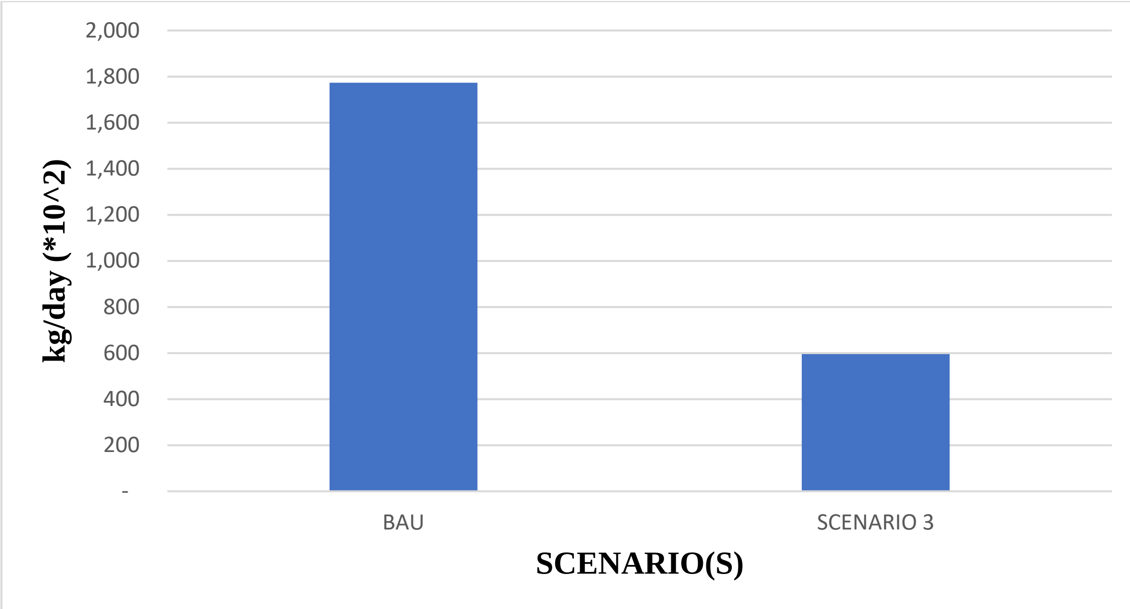


Fig. 5.28: Change in conc. of CO_2 pollutant Weekday in scenario 3.

Fig 5.28 shows that in scenario 3 (weekday) the emission load value of CO_2 decrease strikingly which means converting to all 4-Wheeler & 2 -Wheeler into Electric Vehicle would reduce tailpipe emission significantly. Fig 5.29 It shows percentage reduction in emission compared it to BAU scenario.

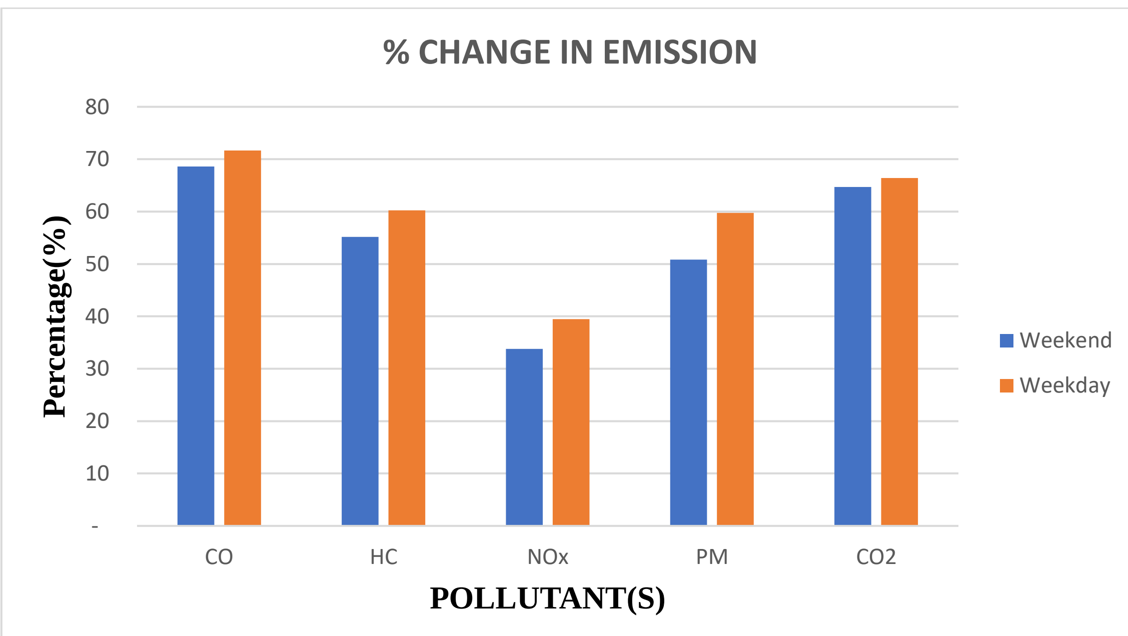


Fig. 5.29: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 3.

5.5 50% Petrol, 20% Diesel and 30%- Electric Vehicle Four-Wheeler Conversion Scenario. - Scenario 4.

In this scenario, it is assumed that Four-wheelers are converted to 50% Petrol, 20% Diesel and 30%- Electric Vehicle ratio resulting in zero emission factors for electric vehicle and emission for petrol and diesel remains as per BAU scenario. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.30 and fig 5.32 and for CO_2 conc. it is shown in fig 5.31 and 5.33. In fig 5.34 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 4 has been shown. Converting 4-Wheeler into 50% Petrol, 20% Diesel and 30%- Electric Vehicle would have positive effect in terms of curbing air pollution.

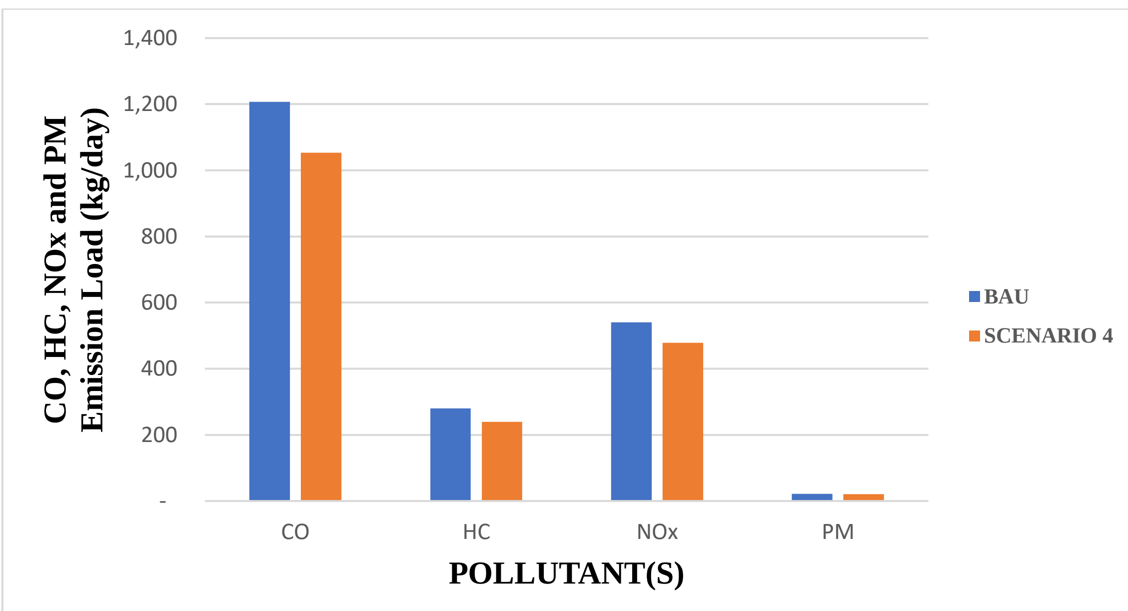


Fig. 5.30: Change in conc. of pollutant Weekend in scenario 4.

Fig 5.30 shows that in scenario 4 (weekend) all the emission load value got decrease satisfactory in CO, HC and NOx and PM which means converting to 50% Petrol, 20% Diesel and 30%- Electric Vehicle Four-Wheeler would reduce tailpipe emission satisfactory.

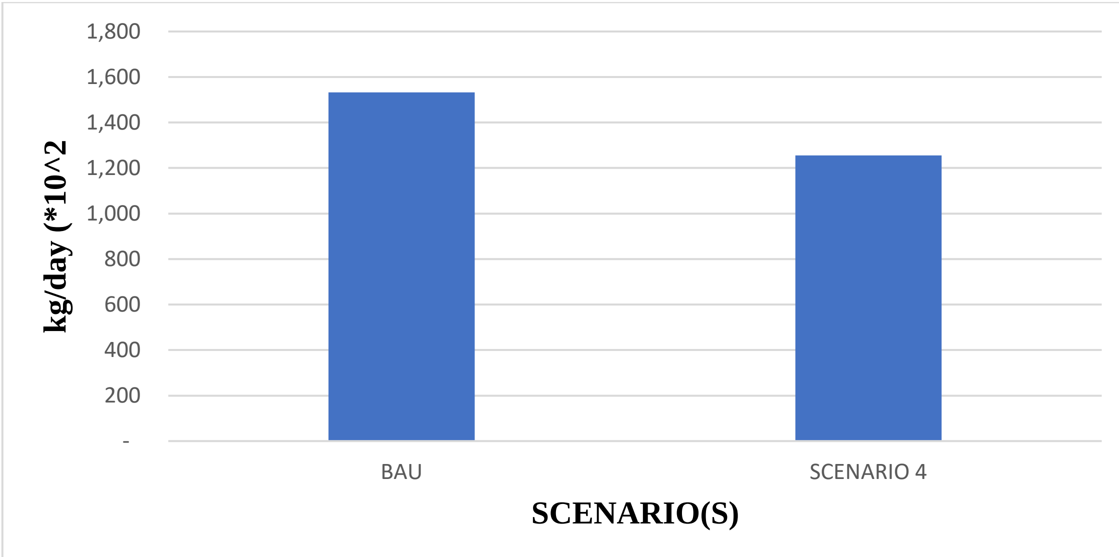


Fig. 5.31: Change in conc. of CO_2 pollutant Weekend in scenario 4.

Fig 5.31 shows that in scenario 4 (weekend) the emission load value of CO_2 decrease strikingly which means converting to 50% Petrol, 20% Diesel and 30%- Electric Vehicle Four-Wheeler would reduce tailpipe emission satisfactory.

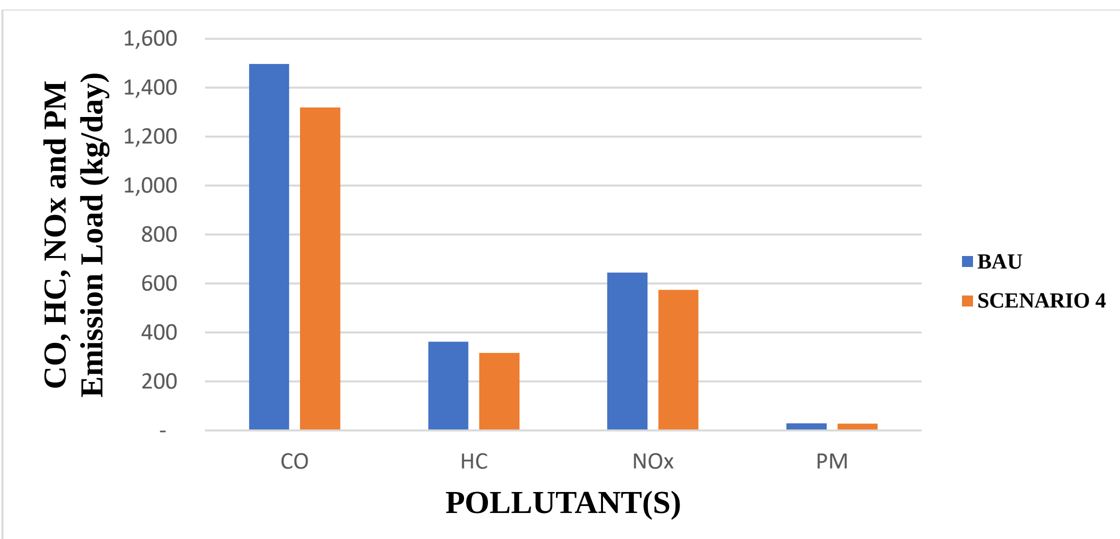


Fig. 5.32: Change in conc. of pollutant Weekday in scenario 4.

Fig 5.32 shows that in scenario 4 (weekday) all the emission load value got decrease satisfactory in CO, HC and NOx and PM which means converting to 50% Petrol, 20% Diesel and 30%- Electric Vehicle Four-Wheeler would reduce tailpipe emission satisfactory.

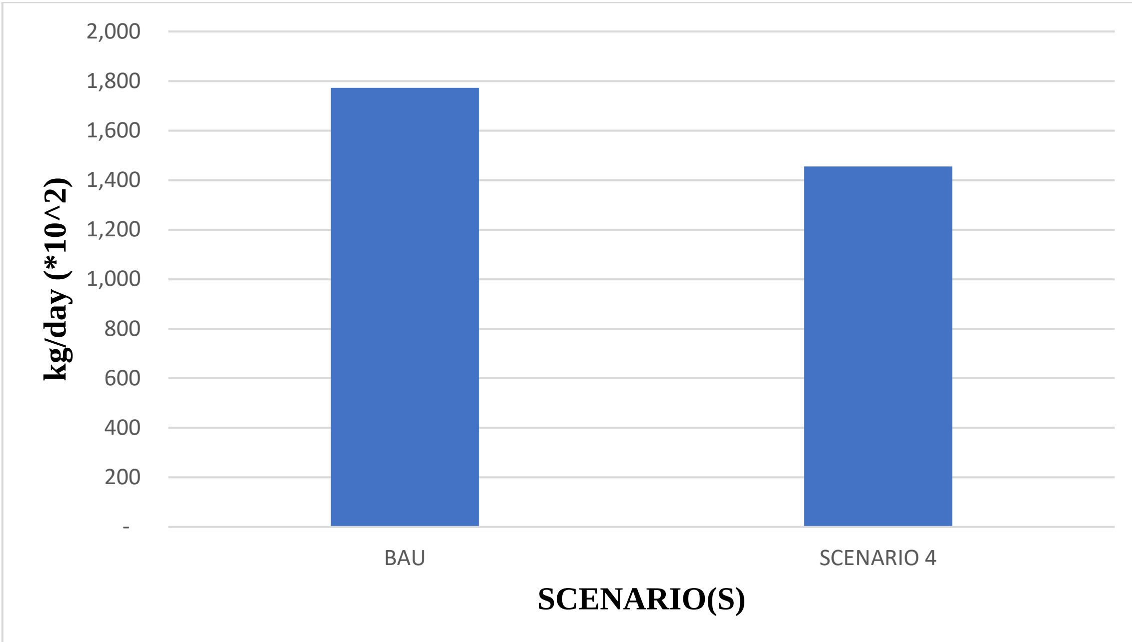


Fig. 5.33: Change in conc. of CO_2 pollutant Weekday in scenario 4.

Fig 5.33 shows that in scenario 4 (weekday) the emission load value of CO_2 decrease strikingly which means converting to 50% Petrol, 20% Diesel and 30%- Electric Vehicle Four-Wheeler would reduce tailpipe emission satisfactory. Fig 5.34 It shows percentage reduction in emission compared it to BAU scenario.

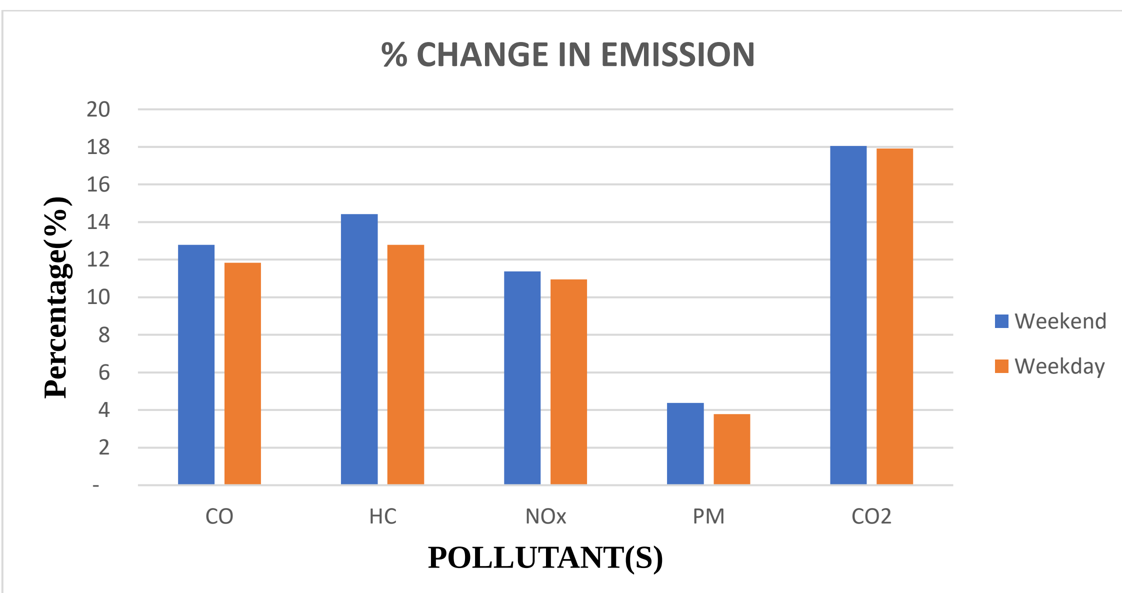


Fig. 5.34: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 4.

5.6 100% Light commercial vehicle into CNG Conversion Scenario - Scenario 5.

In this scenario, it is assumed that all Light commercial vehicle is converted to CNG vehicles, resulting in less emission than LCVs diesel Vehicle due to as CNG is cleaner fuel. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.35 and fig 5.37 and for CO_2 conc. it is shown in fig 5.36 and 5.38. In fig 5.39 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 5 has been shown. Converting Light commercial vehicle into CNG would have positive effect in terms of curbing air pollution.

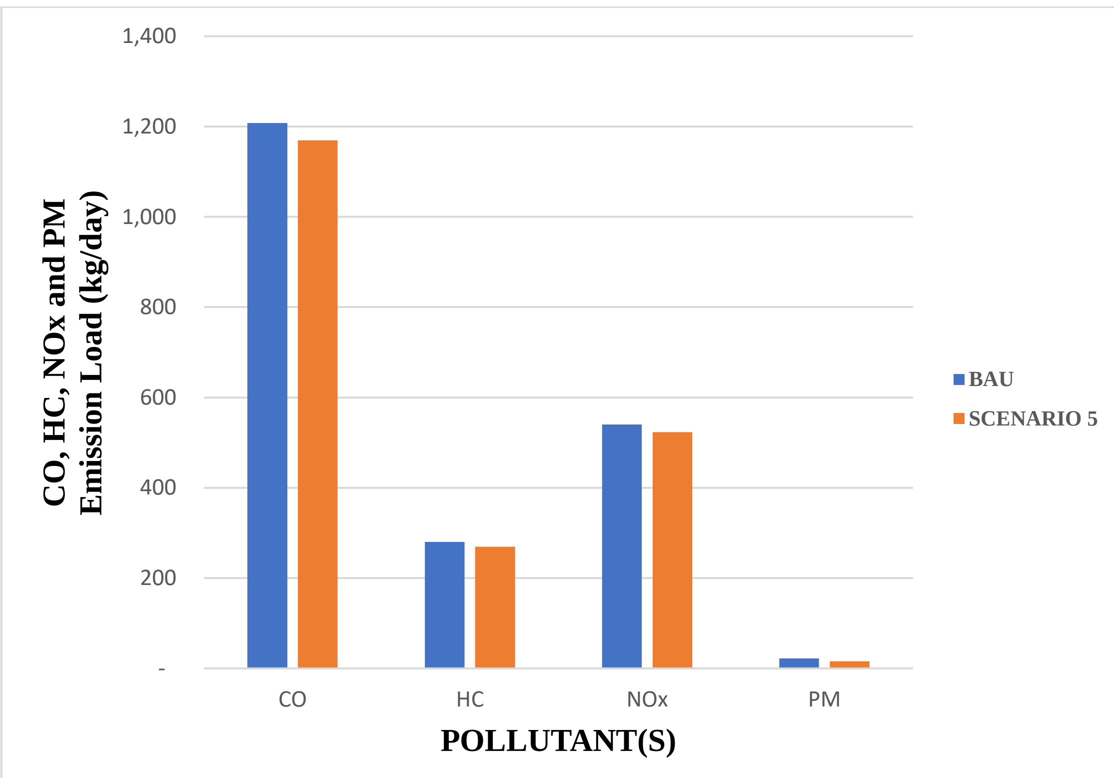


Fig. 5.35: Change in conc. of pollutant Weekend in scenario 5.

Fig 5.35 shows that in scenario 5 (weekend) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to all Light commercial vehicle into CNG would reduce tailpipe emission significantly.

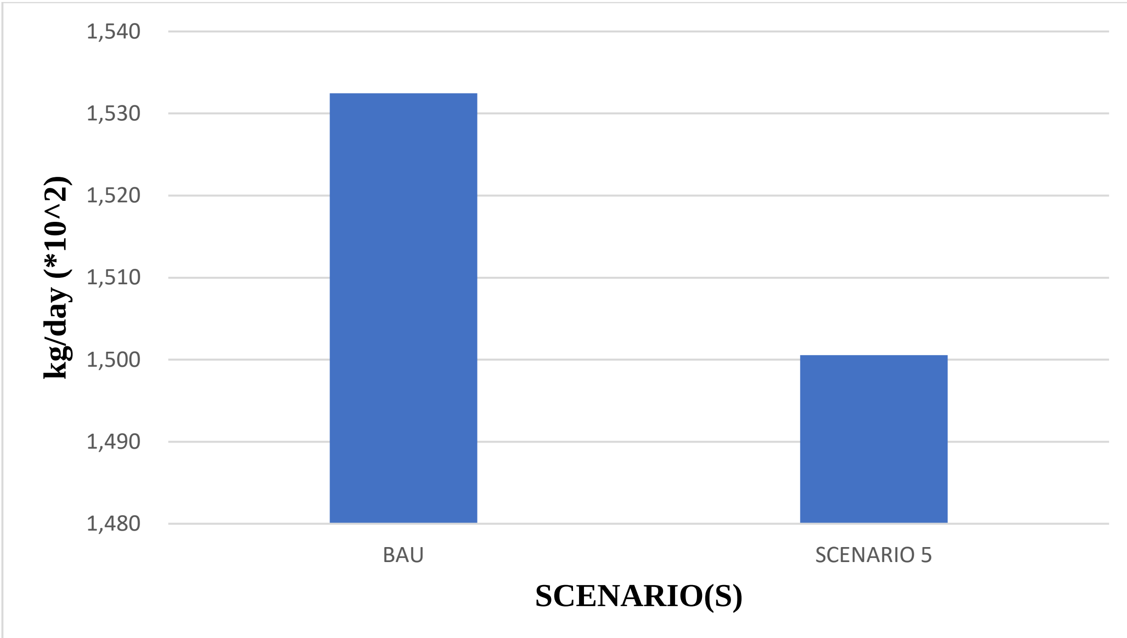


Fig. 5.36: Change in conc. of CO_2 pollutant Weekend in scenario 5.

Fig 5.36 shows that in scenario 5 (weekend) the emission load value of CO_2 decrease strikingly which means converting to Light commercial vehicle into CNG would reduce tailpipe emission significantly.

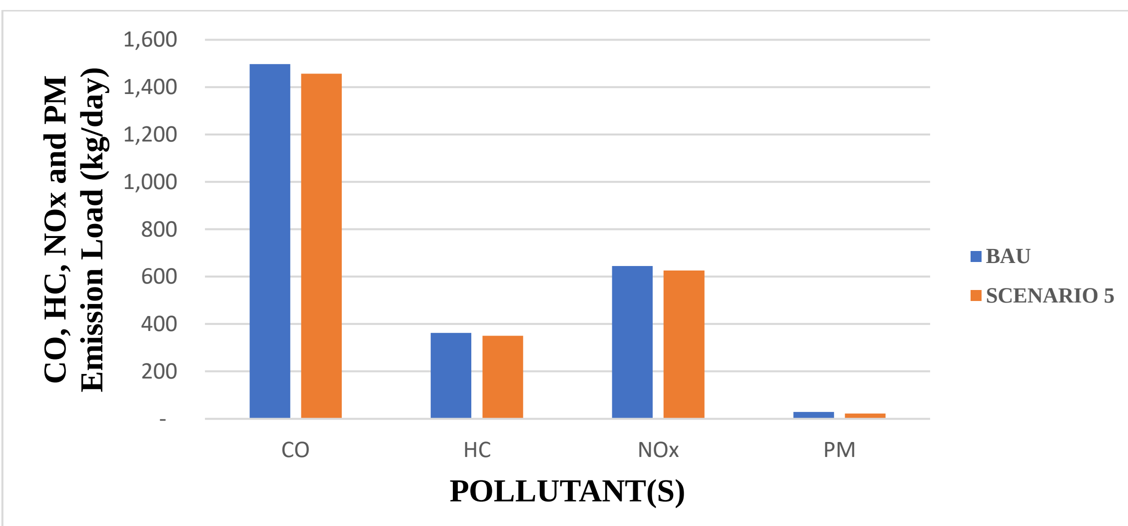


Fig. 5.37: Change in conc. of pollutant Weekday in scenario 5.

Fig 5.37 shows that in scenario 5 (weekday) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to all Light commercial vehicle into CNG would reduce tailpipe emission significantly.

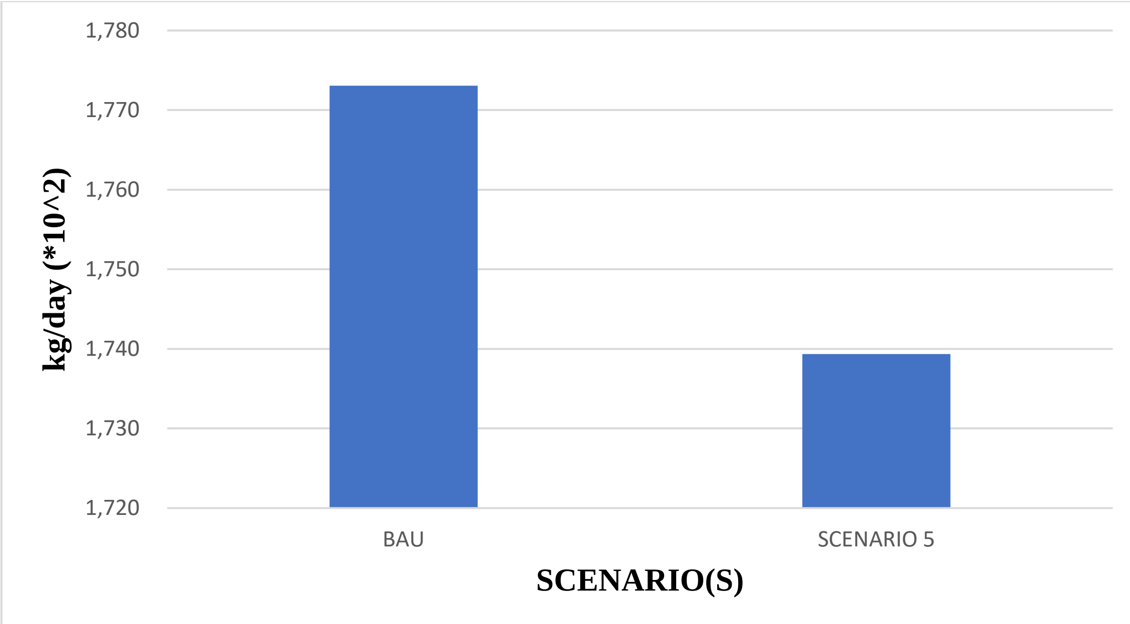


Fig. 5.38: Change in conc. of CO_2 pollutant Weekday in scenario 5.

Fig 5.38 shows that in scenario 5 (weekday) the emission load value of CO_2 decrease strikingly which means converting to Light commercial vehicle into CNG would reduce tailpipe emission significantly. Fig 5.39 It shows percentage reduction in emission compared it to BAU scenario.

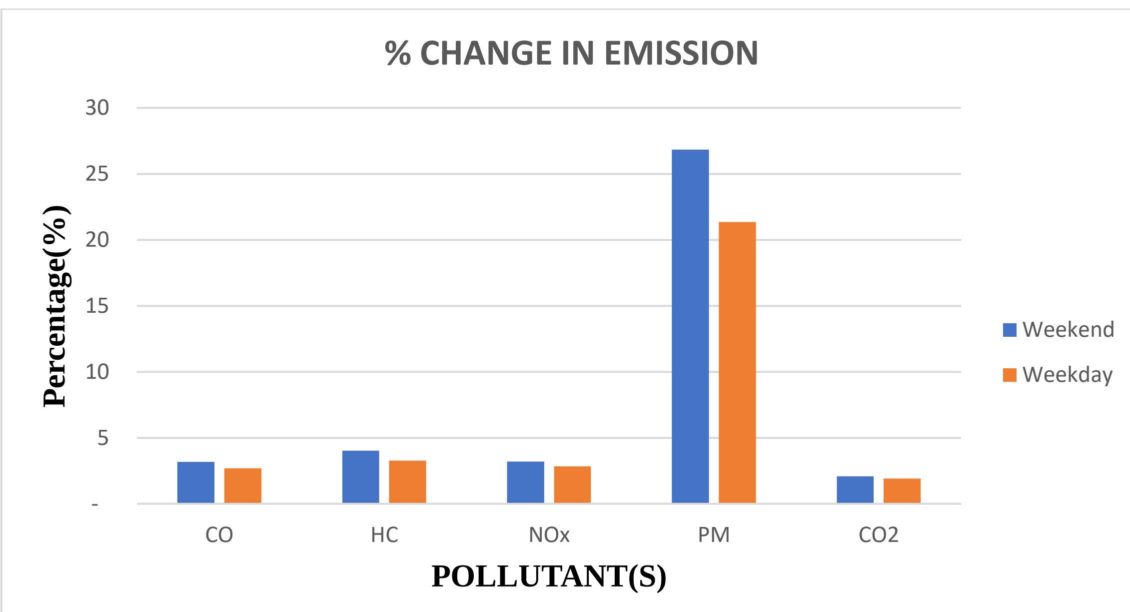


Fig. 5.39: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 5.

5.7 100% Truck vehicle into CNG Conversion Scenario - Scenario 6.

In this scenario, it is assumed that all Truck vehicle is converted to CNG vehicles, resulting in less emission than Truck diesel Vehicle due to as CNG is cleaner fuel. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.40 and fig 5.42and for CO_2 conc. it is shown in fig 5.41 and 5.43. In fig 5.44 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 6 has been shown. Converting Truck vehicle into CNG would have positive CO, and NOx and PM but had negative impact on HC and CO_2 because its emission factors were higher.

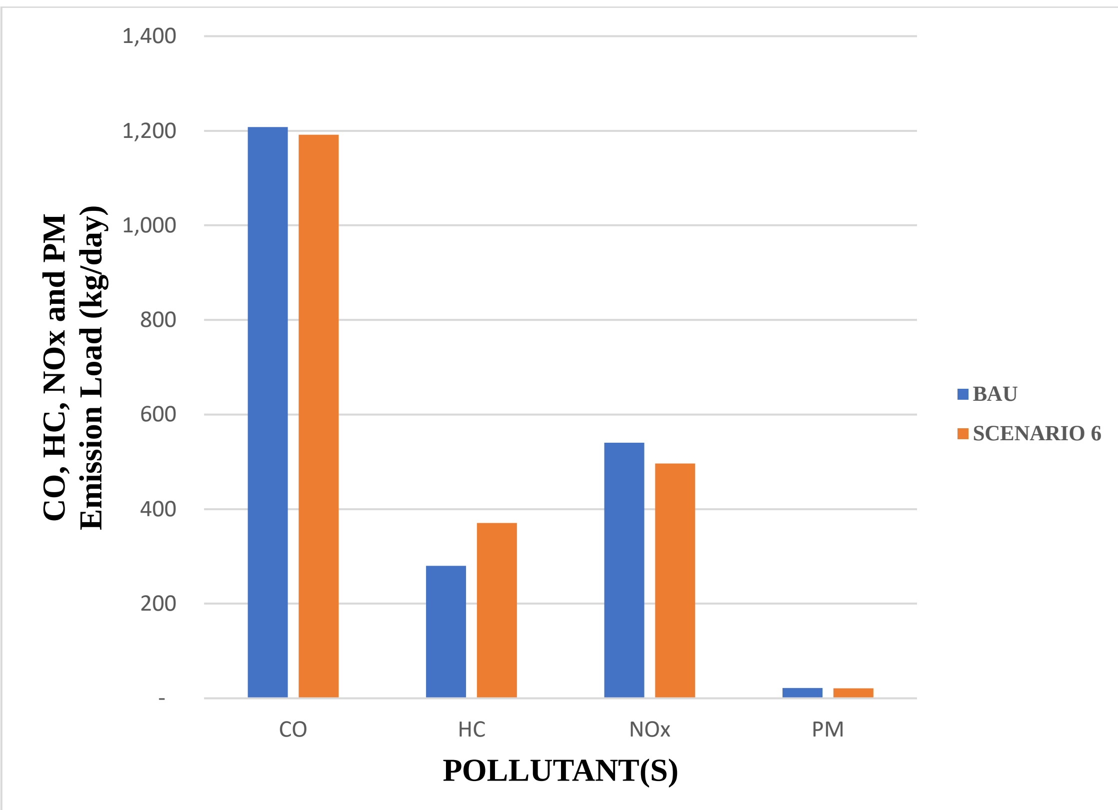


Fig. 5.40: Change in conc. Of pollutant Weekend in scenario 6.

Fig 5.40 shows that in scenario 6 (weekend) the emission load value of HC and PM got increase showing negative effect whereas other emission load CO and NOx decreases the reason for this is emission factor.

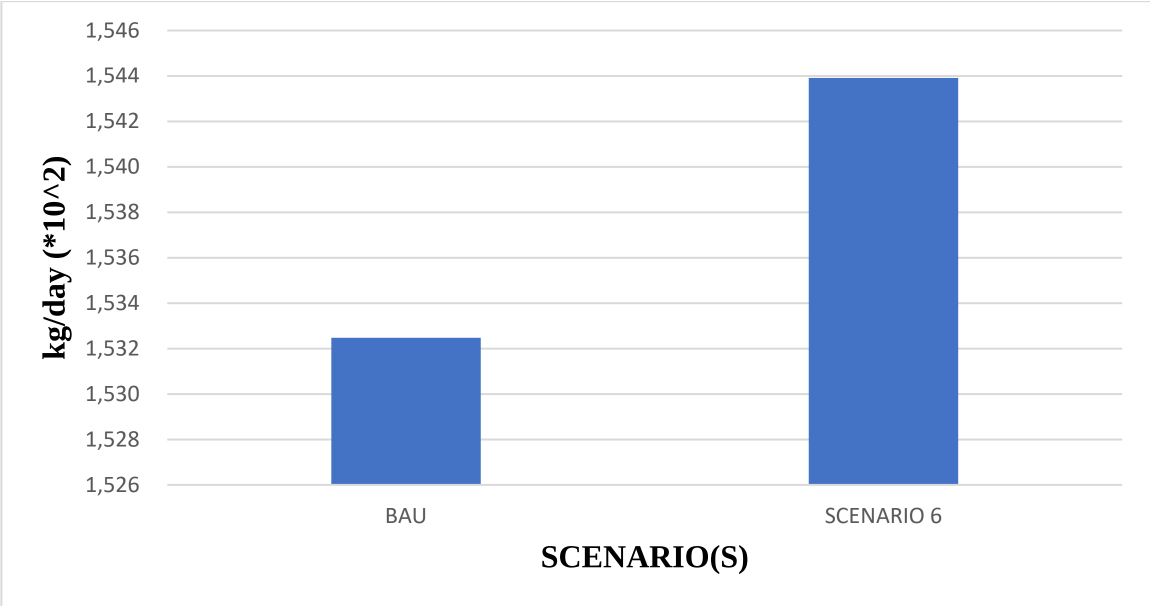


Fig. 5.41: Change in conc. of CO_2 pollutant Weekend in scenario 6.

Fig 5.41 shows that in scenario 6 (weekend) the emission load value of CO_2 emission got increase showing negative effect the reason for this this emission factor.

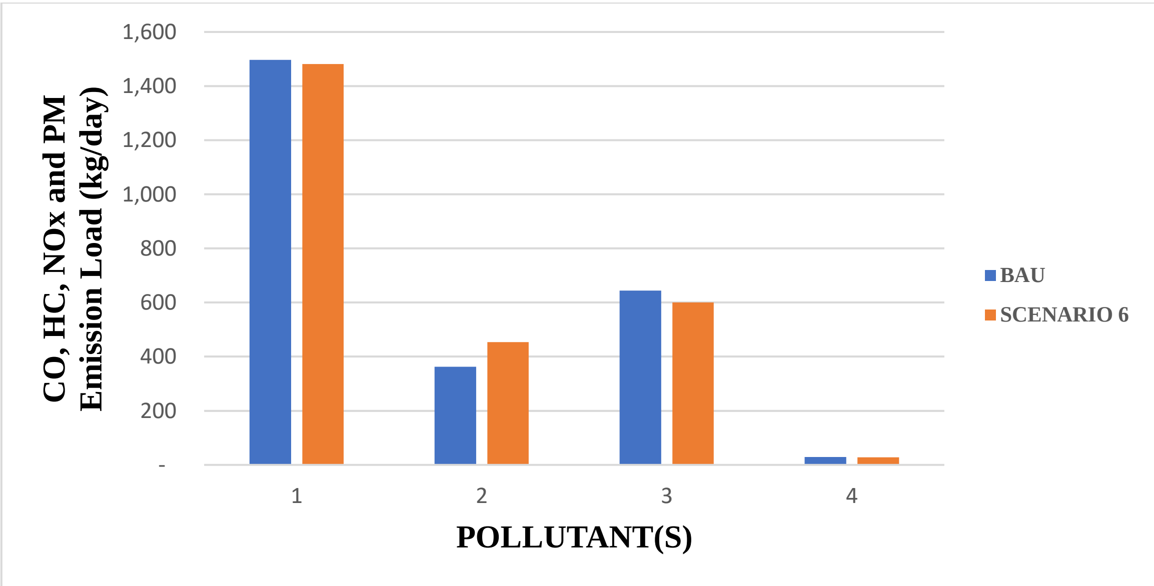


Fig. 5.42: Change in conc. Of pollutant Weekday in scenario 6.

Fig 5.42 shows that in scenario 6 (weekday) the emission load value of HC and PM got increase showing negative effect whereas other emission load CO and NOx decreases the reason for this emission factor.

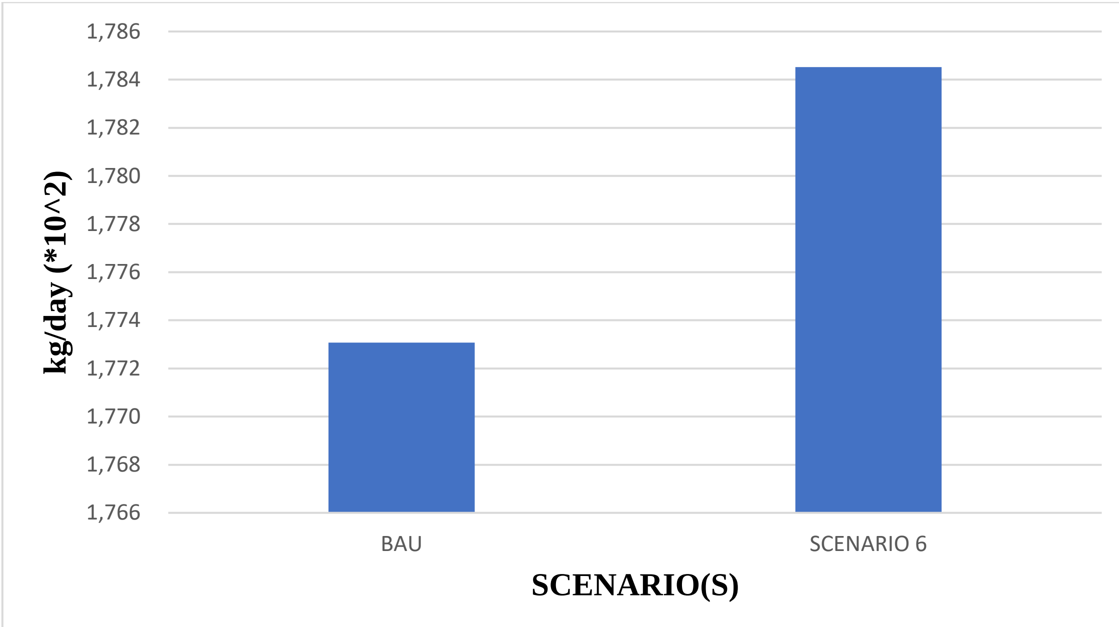


Fig. 5.43: Change in conc. of CO_2 pollutant Weekday in scenario 6.

Fig 5.43 shows that in scenario 6 (weekday) the emission load value of CO_2 emission got increase showing negative effect the reason for this this emission factor. Fig 5.44 It shows percentage reduction in emission compared it to BAU scenario.

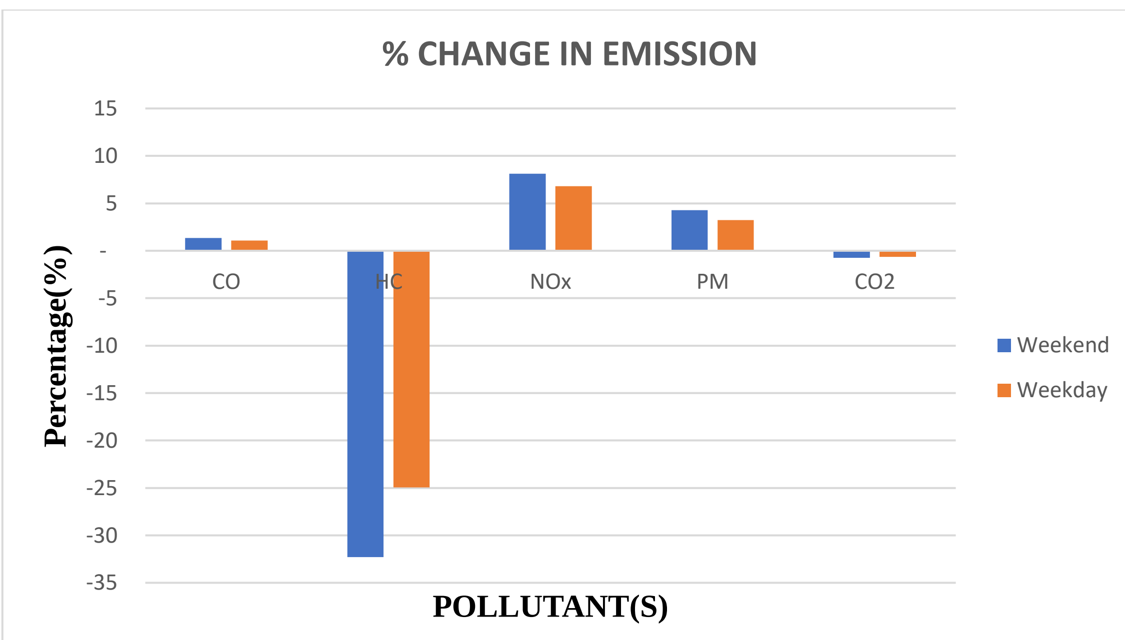


Fig. 5.44: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 6.

5.8 Phasing out vehicles with age >15(petrol) years and >10(Diesel) - Scenario 7.

In this scenario, it is assumed that no vehicle with age greater than 15years for petrol vehicle and 10 years for Diesel vehicle should run on the road hence therefore are removed. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.45 and fig 5.47 and for CO_2 conc. it is shown in fig 5.46 and 5.48. In fig 5.49 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 7 has been shown vehicle with age greater than 15years for petrol vehicle and 10 years for Diesel vehicle should not run on the road hence therefore are removed the results show positive impact on vehicular pollution in terms of curbing them.

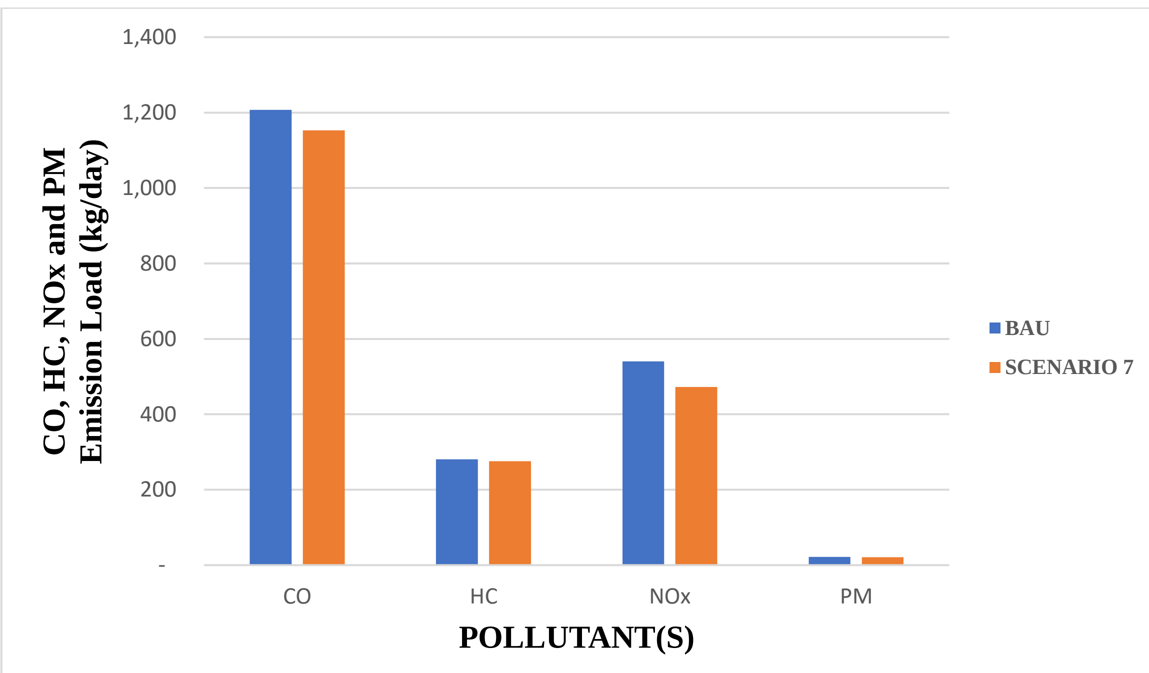


Fig. 5.45: Change in conc. Of pollutant Weekend in scenario 7.

Fig 5.45 shows that in scenario 7 (weekend) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means Phasing out vehicles with age >15(petrol) years and >10(Diesel) would reduce tailpipe emission significantly.

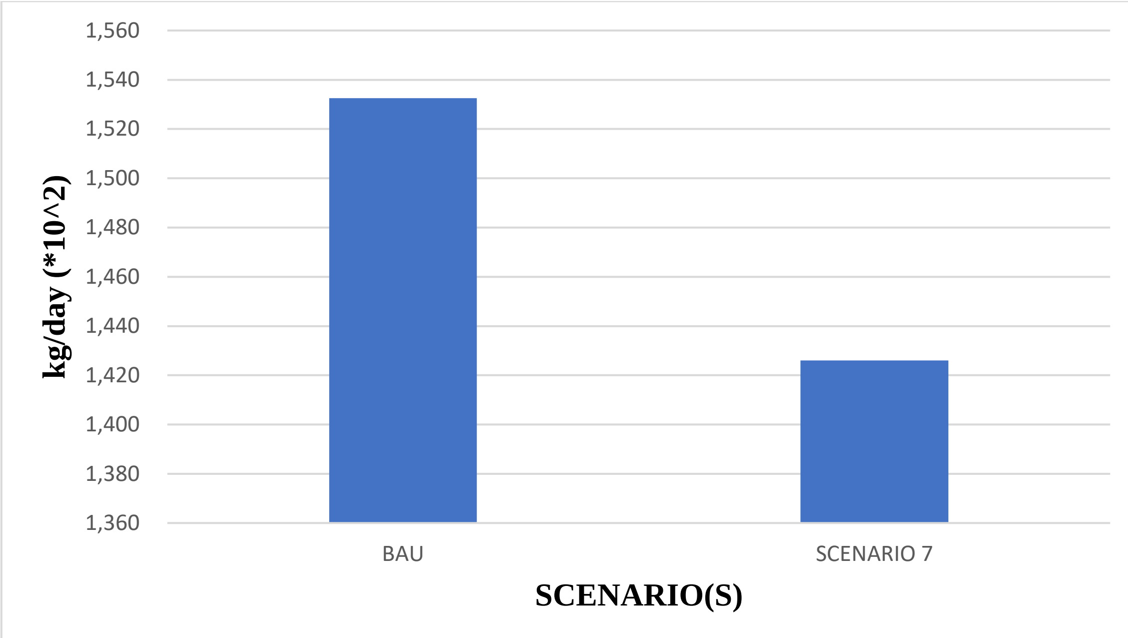


Fig. 5.46: Change in conc. of CO_2 pollutant Weekend in scenario 7.

Fig 5.46 shows that in scenario 7 (weekend) the emission load value of CO_2 decrease strikingly which means Phasing out vehicles with age >15(petrol) years and >10(Diesel) would reduce tailpipe emission significantly.

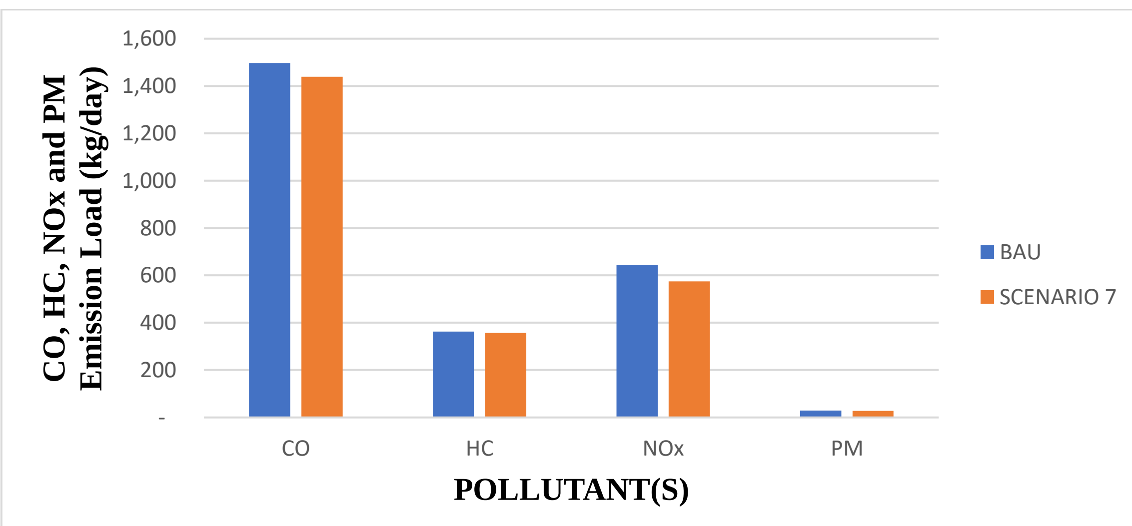


Fig. 5.47: Change in conc. Of pollutant Weekday in scenario 7.

Fig 5.47 shows that in scenario 7 (weekday) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means Phasing out vehicles with age >15(petrol) years and >10(Diesel) would reduce tailpipe emission significantly.

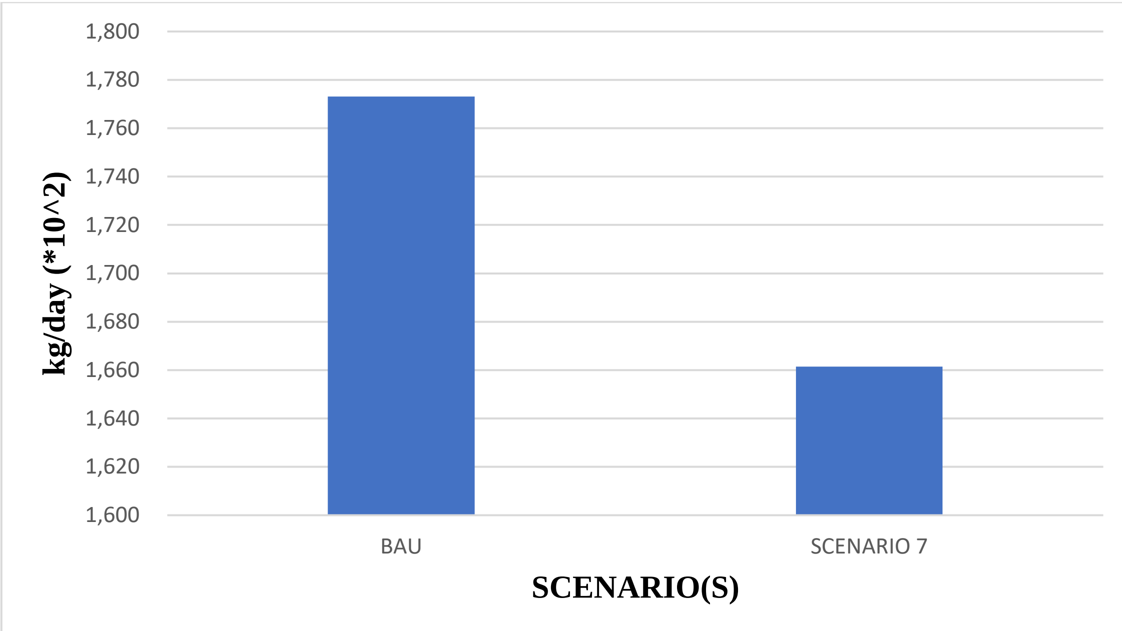


Fig. 5.48: Change in conc. of CO_2 pollutant Weekday in scenario 7.

Fig 5.48 shows that in scenario 7 weekday the emission load value of CO_2 decrease strikingly which means Phasing out vehicles with age >15(petrol) years and >10(Diesel) would reduce tailpipe emission significantly.

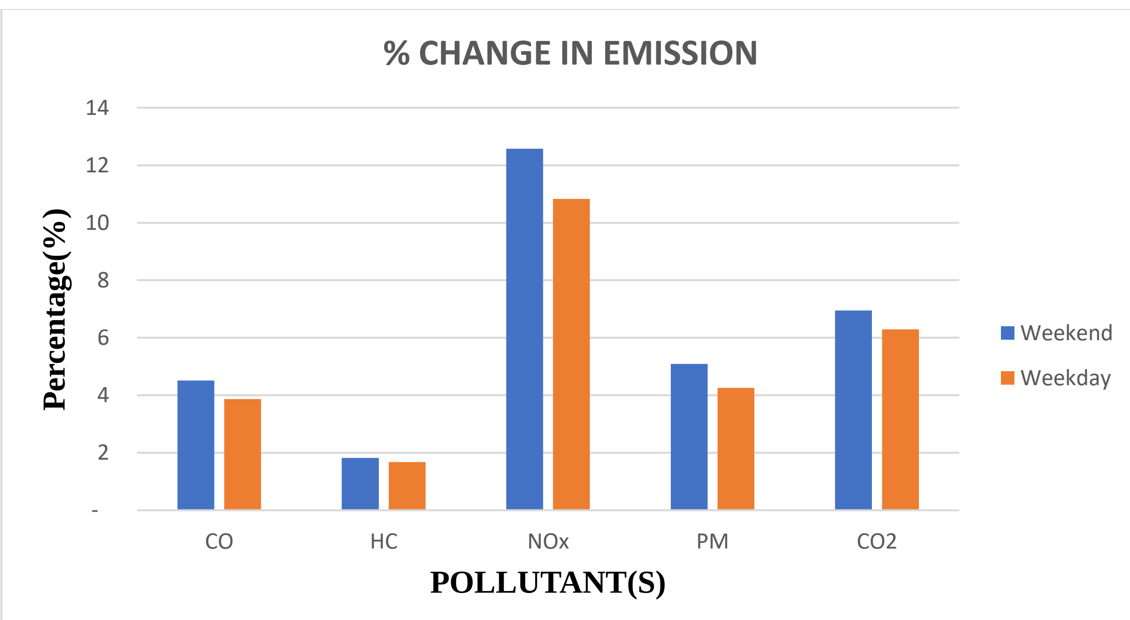


Fig. 5.49: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 7.

5.9 Introduction of BSVI emission standards in 2020 - Scenario 8.

In this scenario, it is assumed that all the vehicles after 2020 are of BSVI norms we would be taking emission factors of euro 6. The outcomes of this scenario are compared with those of the Do-Nothing Scenario, or Business as Usual (BAU) Scenario, to estimate the reduction in pollutant levels. Change in conc. Of CO, HC, NOx and PM for both weekend and weekday are shown in the fig 5.50 and fig 5.51. In fig 5.52 the percentage change in conc. of pollutant(s) Weekend and Weekday in scenario 8 has been shown vehicle with age profile of 0 – 5 years are considered of BSVI emission standards the results show positive impact on vehicular pollution in terms of curbing them.

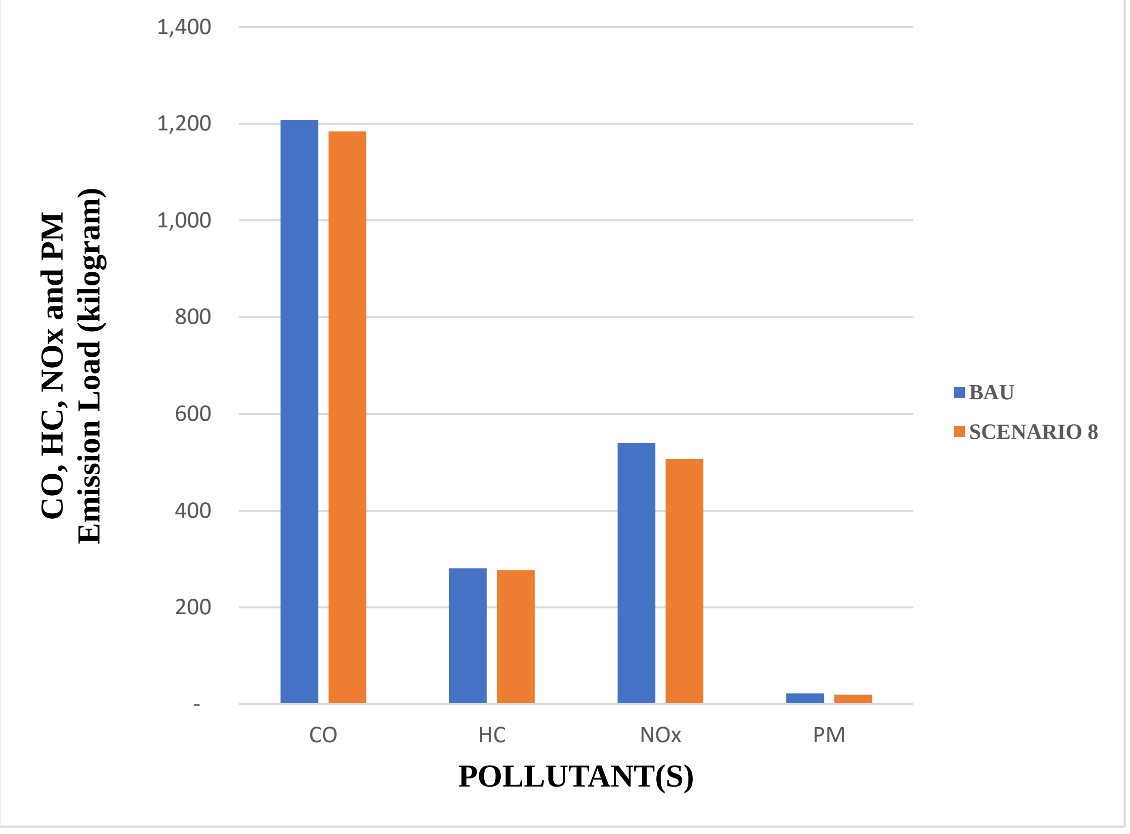


Fig. 5.50: Change in conc. Of pollutant Weekend in scenario 8.

Fig 5.50 shows that in scenario 8 (weekend) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to BSVI emission standards would reduce tailpipe emission significantly.

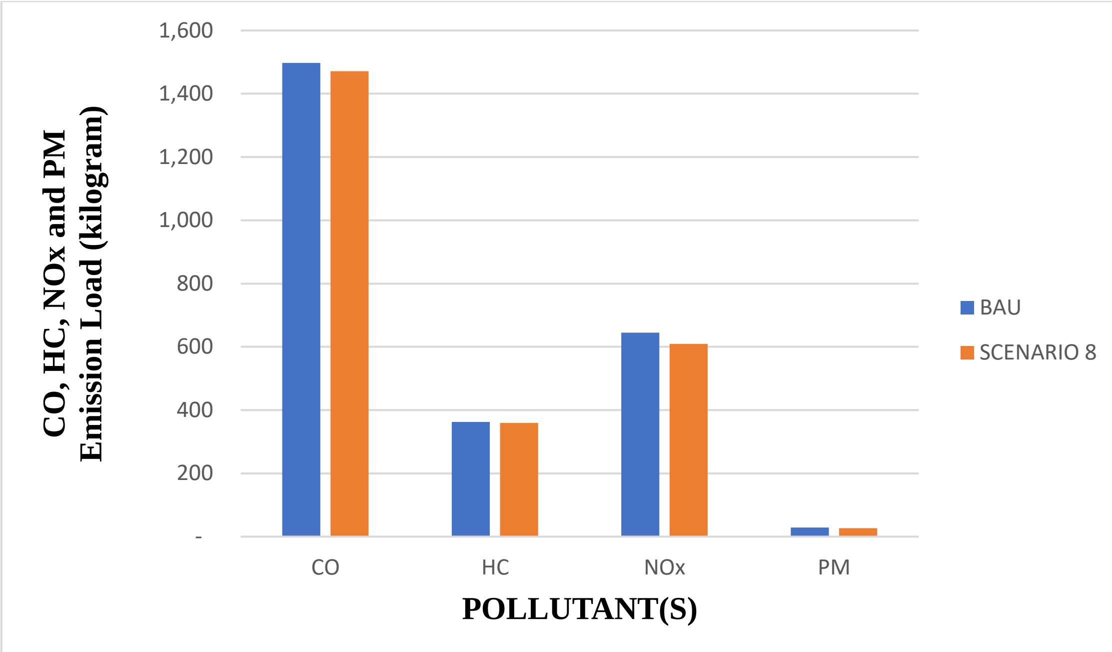


Fig. 5.51: Change in conc. Of pollutant Weekday in scenario 8.

Fig 5.51 shows that in scenario 8 (weekday) all the emission load value got decrease noticeably in CO, HC and NOx and PM which means converting to BSVI emission standards would reduce tailpipe emission significantly. Fig 5.52 It shows percentage reduction in emission compared it to BAU scenario.

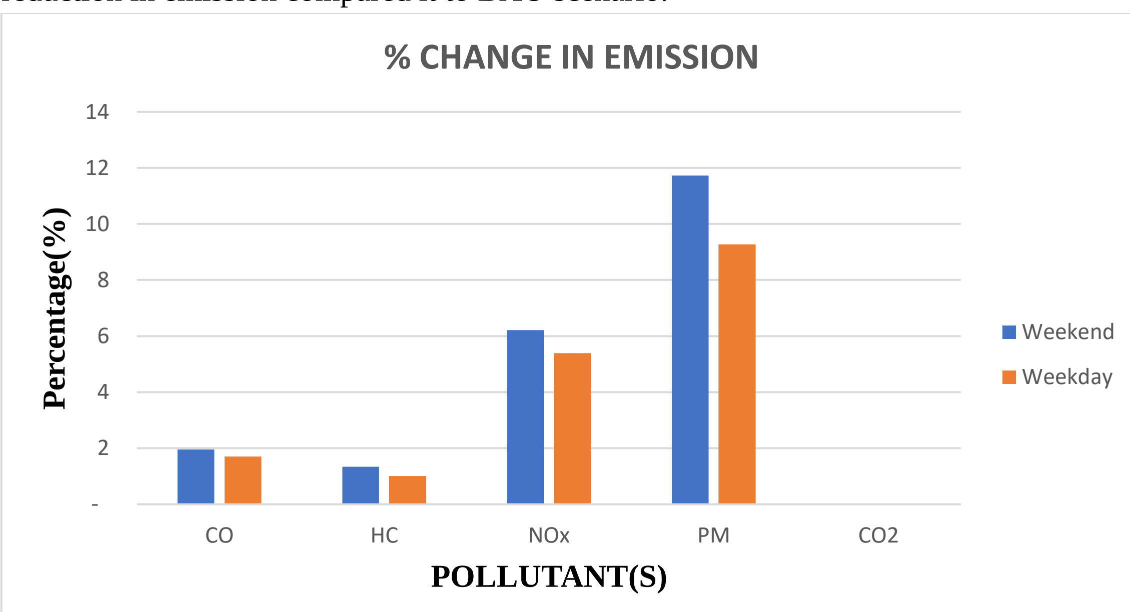


Fig. 5.52: % Change in conc. of pollutant(s) Weekend and Weekday in scenario 8.

CHAPTER 6

CONCLUSION

The primary objective of this study is to estimate vehicular emissions at the CRRI Traffic Intersection and assess the effectiveness of various policies in mitigating air pollution in Delhi. To achieve this, multiple scenarios were developed to provide a comprehensive evaluation of the policies' effectiveness in reducing emissions of CO, HC, PM, NOx, and CO_2, utilizing the CPCB VKT method. These scenarios were then compared with the Business-As-Usual (BAU) scenario to determine their relative efficacy.

The analysis of vehicular emissions under various scenarios revealed significant potential for reduction compared to the Business as Usual (BAU) scenario. The BAU scenario showed substantial emissions of CO, HC, PM, NOx, and CO_2 on both weekends and weekdays. Scenario 1, which involved converting all 2-wheelers to electric vehicles, resulted in notable decreases in all emissions, with reductions up to 49% for NOx on weekdays. Scenario 2, converting all 4-wheelers to electric vehicles, showed even greater reductions, particularly in CO and CO_2 emissions, with decreases up to 60%. The combined conversion of both 2-wheelers and 4-wheelers to electric vehicles in Scenario 3 achieved the highest reductions, with CO_2 emissions dropping by 66% on weekdays. Scenario 4, a mixed conversion of petrol, diesel, and electric vehicles, yielded moderate reductions. Scenario 5, converting light commercial vehicles to CNG, primarily reduced NOx emissions by up to 27%. Scenario 6, converting trucks to CNG, led to slight increases in HC and CO_2 emissions due to specific emission factors, despite reductions in other pollutants. Phasing out older vehicles in Scenario 7 and introducing BSVI emission standards in Scenario 8 both resulted in varied but generally positive impacts, particularly significant reductions in PM and NOx. Overall, the study demonstrates that transitioning to electric vehicles and implementing stricter emission standards can substantially mitigate vehicular pollution in Delhi. It is evident from the above conclusion that Scenario

1,2 and 3 reduces the vehicular pollution significantly. So, we can say that adopting electric vehicle will help to curb vehicular pollution.

6.0 Recommendations

- Changing to electric would reduce vehicular pollution to a very significant level. Which can be seen in scenario 1,2,3.

6.1 Limitations of the study

- The study is limited to only one Urban Road corridor.
- The Value emission factor of truck (CNG) is taken as bus (CNG) due to their similar characteristics.
- Euro 6 emission factors are considered for BSVI scenario.
- Traffic volume is estimated using previous data.
- Old age profile data is considered for current study.
- We have considered emission factor of electric vehicle as zero, but it would have some emission of PM particle due to abrasion and braking.

6.2 Future scope of the study

- The study could be done on more Delhi intersections to estimate emission load for whole Delhi level.

REFERENCES

[1] Unep, “UNEP Annual Report 2021,” UNEP, https://www.unep.org/annualreport/2021/ (accessed May 8, 2024).

[2] “Air pollution note – data you need to know,” UNEP, https://www.unep.org/interactives/air-pollution-note/ (accessed May 8, 2024).

[3] Global burden of disease study 2017, https://www.healthdata.org/sites/default/files/files/policy_report/2019/GBD_2017_Booklet.pdf (accessed May 9, 2024).

[4] A. S. Nagpure, K. Sharma, and B. R. Gurjar, “Traffic induced emission estimates and trends (2000–2005) in Megacity Delhi,” Urban Climate, vol. 4, pp. 61–73, Jul. 2013. doi:10.1016/j.uclim.2013.04.005

[5] F. B. Bennitt, S. S. Wozniak, K. Causey, K. Burkart, and M. Brauer, “Estimating disease burden attributable to household air pollution: New methods within the global burden of disease study,” The Lancet Global Health, vol. 9, Mar. 2021. doi:10.1016/s2214-109x(21)00126-1

[6] J. H. Barnes, T. J. Chatterton, and J. W. S. Longhurst, “Emissions vs exposure: Increasing injustice from road traffic-related air pollution in the United Kingdom,” Transportation Research Part D: Transport and Environment, vol. 73, pp. 56–66, Aug. 2019. doi:10.1016/j.trd.2019.05.012

[7] “Transport Department Government of NCT of Delhi,” Transport Department, https://transport.delhi.gov.in/ (accessed May 11, 2024).

[8] R. Lindsey, “Climate change: Atmospheric carbon dioxide,” NOAA Climate.gov, https://www.climate.gov/news-features/understanding-climate/climate-change-atmospheric-carbon-dioxide (accessed May 11, 2024).

[9] C. Rosenzweig, W. Solecki, S. A. Hammer, and S. Mehrotra, “Cities lead the way in climate–change action,” Nature, vol. 467, no. 7318, pp. 909–911, Oct. 2010. doi:10.1038/467909a

[10] C. D. Idso, S. B. Idso, and R. C. Balling, “An intensive two-week study of an Urban CO_2 Dome in Phoenix, Arizona, USA,” Atmospheric Environment, vol. 35, no. 6, pp. 995–1000, Jan. 2001. doi:10.1016/s1352-2310(00)00412-x

[11] M. D. Gajbhiye, S. Lakshmanan, R. Aggarwal, N. Kumar, and S. Bhattacharya, “Evolution and mitigation of vehicular emissions due to India’s Bharat stage emission

standards – A case study from Delhi," Environmental Development, vol. 45, p. 100803, Mar. 2023. doi:10.1016/j.envdev.2023.100803

[12] I. Sharma, R. Padmanabhi, A. K. Dikshit, and M. K. Chandel, "Urban transport emissions under current and alternative mitigation policy scenarios for the Mumbai Metropolitan Region," Case Studies on Transport Policy, vol. 12, p. 101001, Jun. 2023. doi:10.1016/j.cstp.2023.101001

[13] M. Advani et al., "Gradual Sustainability Approach for urban transport through subtle measures," Current Science, vol. 122, no. 9, p. 1036, May 2022. doi:10.18520/cs/v122/i9/1036-1043

[14] M. R. Aosaf, Y. Wang, and K. Du, "Comparison of the emission factors of air pollutants from gasoline, CNG, LPG and diesel fueled vehicles at Idle Speed," Environmental Pollution, vol. 305, p. 119296, Jul. 2022. doi:10.1016/j.envpol.2022.119296

[15] N. Raparthi and H. C. Phuleria, "Assessing Mumbai's in-use vehicular characteristics, current emissions, and future projections under various policy interventions," Journal of Cleaner Production, vol. 375, p. 134145, Nov. 2022. doi:10.1016/j.jclepro.2022.134145

[16] M. Advani, N. Sharma, and R. Dhyani, "Mobility change in Delhi due to Covid and its' immediate and long term impact on demand with intervened non motorized transport friendly infrastructural policies," Transport Policy, vol. 111, pp. 28–37, Sep. 2021. doi:10.1016/j.tranpol.2021.07.008

[17] Advani, Mukti & Sharma, Niraj. (2021). Potential Emission Reduction Due To Improved Non- Motorized Transport Friendly Infrastructure-A Case Study Of Delhi. 49. 10-19.

[18] D. Das, P. P. Kalbar, and N. R. Velaga, "Pathways to decarbonize passenger transportation: Implications to India's climate budget," Journal of Cleaner Production, vol. 295, p. 126321, May 2021. doi:10.1016/j.jclepro.2021.126321

[19] Ch. R. Sekhar, N. S. Sharma, M. Advani, and R. Kumar, "Quantification of reduction in air pollution due to bypassing traffic in Delhi, India," Current Science, vol. 120, no. 10, p. 1600, May 2021. doi:10.18520/cs/v120/i10/1600-1610

[20] Srivastava, S., & Shukla, A. K. (2021). Vehicular Emission Estimates of Various Air Pollutants in Residential Region of Lucknow.

[21] I. Sharma and M. K. Chandel, "Will electric vehicles (EVS) be less polluting than conventional automobiles under Indian city conditions?," Case Studies on Transport Policy, vol. 8, no. 4, pp. 1489–1503, Dec. 2020. doi:10.1016/j.cstp.2020.10.014

[22] R. Dhyani, N. Sharma, And M. Advani, "Estimation Of Fuel Loss And Spatial–Temporal Dispersion Of Vehicular Pollutants At A Signalized Intersection In Delhi City, India," Wit Transactions On Ecology And The Environment, Sep. 2019. Doi:10.2495/Air190231

[23] N. Sharma, P. P. Kumar, R. Dhyani, C. Ravisekhar, and K. Ravinder, "Idling fuel consumption and emissions of air pollutants at selected signalized intersections in Delhi," Journal of Cleaner Production, vol. 212, pp. 8–21, Mar. 2019. doi:10.1016/j.jclepro.2018.11.275

[24] Soumyajohnson, P., & Sathikumar, R. (2019). Estimation of vehicular emission at major road corridors in Thiruvananthapuram city.

[25] R. Singh, C. Sharma, and M. Agrawal, "Emission inventory of trace gases from road transport in India," Transportation Research Part D: Transport and Environment, vol. 52, pp. 64–72, May 2017. doi:10.1016/j.trd.2017.02.011

[26] D. Mishra and P. Goyal, "Estimation of vehicular emissions using dynamic emission factors: A case study of delhi, India," Atmospheric Environment, vol. 98, pp. 1–7, Dec. 2014. doi:10.1016/j.atmosenv.2014.08.047

[27] "Transport Department Government of NCT of Delhi," Transport Department, https://transport.delhi.gov.in/ (accessed May 11, 2024).

[28] Delhi Statistical Hand Book, 2023, https://des.delhi.gov.in/sites/default/files/DES/generic_multiple_files/statistical_hand_book_2023.pdf (accessed May 11, 2024).

[29] Road Transport Year Book (2019 - 20), https://morth.nic.in/sites/default/files/RTYB_Publication_2019_20%20(1).pdf (accessed May 9, 2024).

[30] World Air Quality Report 2020, https://www.iqair.com/world-most-polluted-cities/world-air-quality-report-2020-en.pdf (accessed Jun. 1, 2024).

[31] CRRI report "Estimation Of Fuel Losses And Assessment Of Air Quality At Selected Traffic Intersection(S) In Delhi" Sponsored By CPCB Central Pollution Control Board (Ministry Of Environment Forests And Climate Change, Govt. Of India) CSIR- CRRI Transport Planning And Environment Division, August 2020.