“VEHICULAR EMISSION INVENTORY FOR SHIMLA CITY”

A

PROJECT REPORT

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

of

BACHELOR OF TECHNOLOGY

IN

CIVIL ENGINEERING

Under the supervision

of

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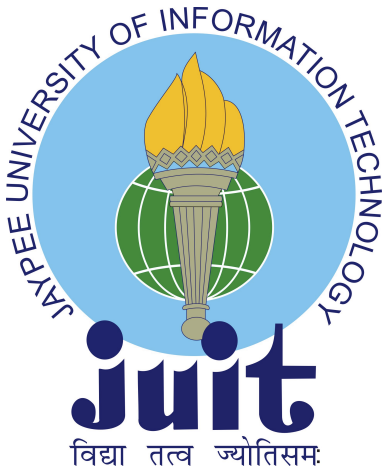

JAYPEE UNIVERSITY OF INFORMATION TECHNOLOGY

WAKNAGHAT, SOLAN-173234

HIMACHAL PRADESH, INDIA

MAY-2021

DECLARATION

I hereby declare that the work presented in the Project report entitled **"VEHICULAR EMISSION INVENTORY OF SHIMLA CITY"** submitted for partial fulfilment of the requirements for the degree of Bachelor of Technology in Civil Engineering at **Jaypee University of Information Technology, Waknaghat** is an authentic record of my work carried out under the supervision of **Dr. Rajiv Ganguly**. This work has not been submitted elsewhere for the reward of any other degree/diploma. I am fully responsible for the contents of my project report.

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CERTIFICATE

This is to certify that the work which is being presented in the project report titled **"VEHICULAR EMISSION INVENTORY OF SHIMLA CITY"** in partial fulfilment of the requirements for the award of the degree of Bachelor of Technology in Civil Engineering submitted to the Department of Civil Engineering, **Jaypee University of Information Technology, Waknaghat** is an authentic record of work carried out by **Ankit Thakur (171646)**, **Chander Bhushan (171652)** and **Passang Wangdi (171674)** during a period from August, 2020 to May, 2021 under the supervision of **Dr. Rajiv Ganguly** (Associate professor), Department of Civil Engineering, Jaypee University of Information Technology, Waknaghat.

The above statement made is correct to the best of our knowledge.

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Had there been no continuous supervision and support from our project guide Dr. Rajiv Ganguly, our project during such critical times of pandemic would have been a failure. Some input data that we are looking for aren't found online, so our guide has been our source most of the time. We would like to sincerely thank Dr. Rajiv Ganguly (Associate Professor) for his valuable guidance and kind supervision. We would like thank our lecturers for kindly answering our questions and clearing our doubts regarding project whenever we ask them.

We would like to express our gratitude to all of them. We will remain ever indebted for such a good support system we have got from all aforementioned individuals.

ABSTRACT

Air pollution is a major issue that concerns everyone around the world and in fact we have seen so much degradation in air quality from the past few couple of decades. The technical advancements are on continuous boom and thus air is polluted at very high rate. The major sources of air pollution are categorised as point source, line source and area source amongst which line source contributes the highest portion of air degradation nowadays. The transport sector specifically is the highest contributing source of air pollution these days because we have seen exponential rise in number of vehicles around the globe. The criteria pollutants produced from vehicles are calculated using different methods and are studied for developing vehicular emission inventory for a particular area. This vehicular emission inventory gives us the detailed information of type of pollutants and the amount of each pollutants produced from different types of vehicles. For developing vehicular emission for Shimla city we have used COPERT5 which is European based software. We have gone through reports and their reviews and found that COPERT5 is a simple and efficient software for finding out emissions from transport sector. We have not seen many such studies done for cities in India and those done have used other softwares. So we are doing as a part of study to check whether Shimla city is a smart city or not but only vehicular emissions doesn't constitute the feature of smart city.

Keywords: Vehicular emission inventory, COPERT5, Pollutants, Shimla

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LIST OF ACRONYMS & ABBREVIATIONS

COPERT	COmputer Programme to calculate Emissions from Road Transport
CO	Carbon Monoxide
NO_x	Nitrogen Oxide
VOC	Volatile Organic Compounds
PM	Particulate Matter
EU	European Union
UNFCCC	United Nations Framework Convention on Climatic Change
LRTAP	Long-Range Transboundary Air Pollution
USEPA	United States Environmental Protection Agency
IPCC	Intergovernmental Panel on Climate Change
SNAP	Standardised Nomenclature for Air Pollutants
CPCB	Central Pollution Control Board
RTO	Regional Transport Office
CNG	Compressed Natural Gas
UNECE	United Nation Economic Commission for Europe
WHO	World Health Organisation
AOI	Air Quality Index
HDT	Heavy Duty Truck
LCVs	Light Commercial Vehicles
PCs	Passenger Cars
Mpds	Mopeds
mtcs	Motorcycles
Rgd	Rigid
Artc	Articulated

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CHAPTER 1

INTRODUCTION

1.1 GENERAL

An emission inventory is basically computing the different pollutants that are being released in our atmosphere [21] by different sources in a region. The major sources responsible for this in the city are transport, industries, power plants, Diesel Generator (DG) sets, domestic, road dust emissions and construction activities.

In general, an emission inventory is the record of the estimated amount of pollutants emitted from mobile and stationary sources in a region within a specific period of time. These inventories are vital components in determining the air quality planning and modelling part.

An emission inventory can be more clearly understood by the following aspects:

- **Why**: The different activities that are responsible for emissions.
- **What**: Identification of different pollutants that are released during emissions and determining their physical and chemical properties.
- **Where**: The area where emissions are taking place.
- **When**: Time interval over which the emissions are being calculated.
- **How**: The procedure to be adopted.

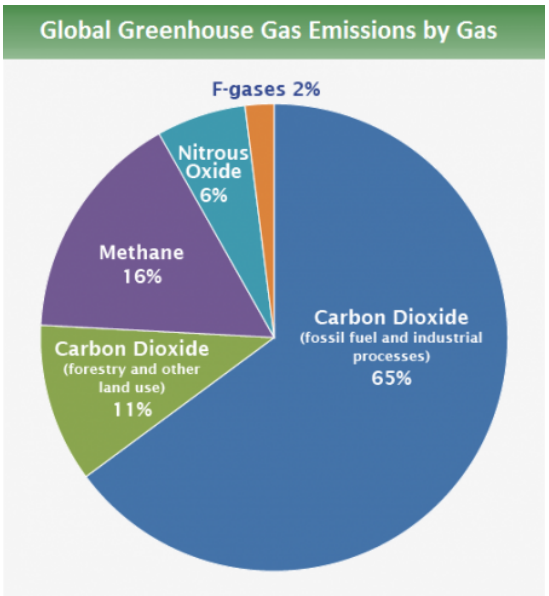

Fig 1.1: Global Greenhouse Gas Emissions

1.2 OBJECTIVES OF EMISSION INVENTORY

- To study the types of sources associated with emission inventory i.e. point sources, area sources and line sources. The major focus in the report is on the line sources which includes the vehicular or the road sources.
- To study the different types of air pollutant emissions from vehicles and hence determine the total emissions from the transport sector.
- To analyse Shimla City in terms of vehicular emissions.
- To determine the concentration of different pollutants in Shimla city.

1.3 EMISSION INVENTORY USE

Emissions that are released in our atmosphere on daily basis can pose serious threat and is responsible for environmental pollution. Hence details and knowledge about emissions is important in understanding [21] different environmental problems and steps that can be taken towards solving these. Emission based inventory therefore are crucial in providing various details.
Emission inventories are established for various purposes:

- Inventories are used by the lawmakers in order to access and gain knowledge on different sources of pollutants and then accordingly taking the necessary steps towards solving these.
- Various inventories of human based intervention and natural emissions are used as inputs by various scientists in their air quality model. Basically emission inventories are an essential input to mathematical models that estimate quality of air.
- Inventories are key in raising public awareness regarding different sources of pollution.

1.4 TRANSPORT SECTOR IN SHIMLA CITY

As per census 2011, Shimla city is escalated over an area of 35.34 sq.km with a population [22] of around 170,000.Since then the population of the city is increasing rapidly on daily basis with consistent increase in figure of vehicle without any increase in the length of road. The number of vehicles running on the roads has more than doubled in the last 14 years and thus taking the registered vehicle count from 31,228 in 2005 to about 77,939 today. It has been observed that vehicles running on roads are major contributor towards pollution in the city. Hence as a result more and more amount of pollutants is being released in the atmosphere.

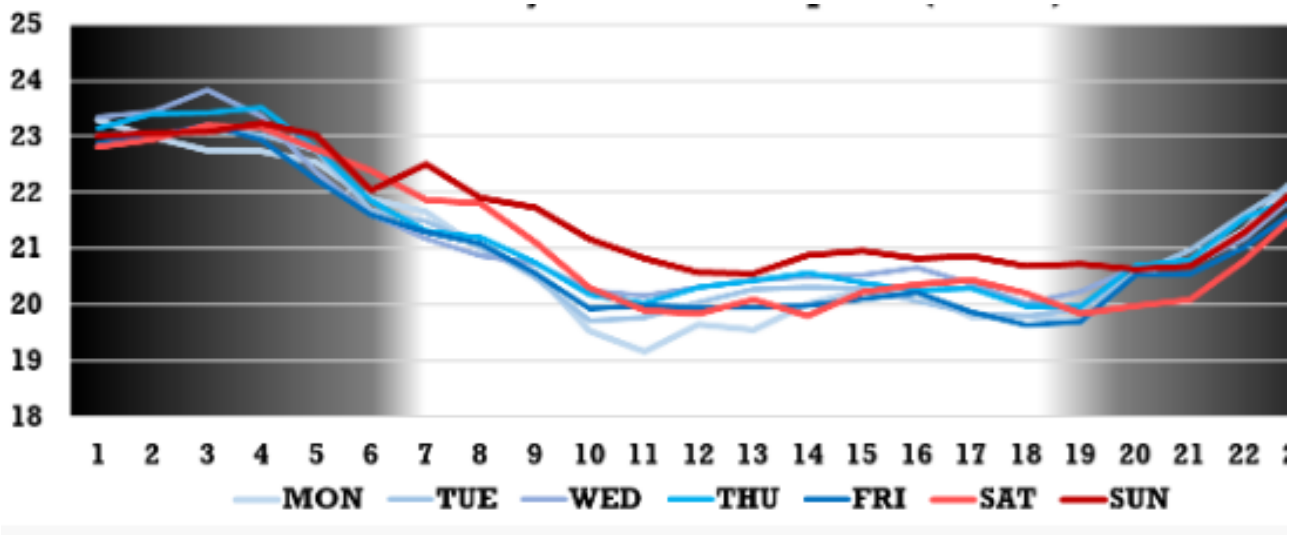

Fig 1.2: Shimla-hourly urban traffic speeds (km per hour)

According to the Pollution Control Board, 80 per cent of air pollution in the state is due to diesel vehicles. Apart from this, the reason for increasing air pollution is the debris being thrown on the roadside. Twenty years old diesel vehicles which are still running on the roads of the state are the main reason for the high pollution levels here.

The figure below shows emissions by different sources and it is quite evident that vehicles being propelled by diesel contribute to more amount of emissions in Shimla city

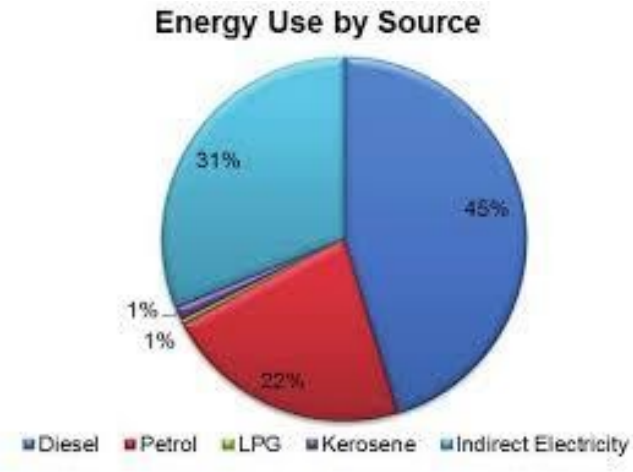

Fig 1.3: Emissions by different sources for Shimla City

1.5 EMISSIONS DUE TO AIR POLLUTANTS

Different motor vehicle while running on roads emits various pollutants in the atmosphere, these pollutants causes air quality problems and is often responsible for various negative impacts on human health.

Different types of pollutant from vehicles include the following:

Hydrocarbons:

These are the partially or completely burned fuels which are toxic in nature and are responsible for atmospheric [25] pollution and change in climate. Many of these are volatile and are known as Volatile organic compounds (VOCs).

Carbon monoxide (CO):

When the carbon fuels are not burnt totally then carbon monoxide gas is formed. Both on road sources and non road sources accounts for CO emissions.

Nitrogen oxides (NO_x)-

It is formed when both oxygen and nitrogen gases undergoes reaction at high temperature. It may cause harm to human respiratory system if its exposure is long term.

Particulate matter-

It may be called as soot or smoke and are described as solid particles found in the air. Diesel exhaust is a major contributor to PM pollution.

Sulfur oxide (SO_x)-

These are emitted from motor vehicles burning fuel having a high amount of sulphur.

1.6 AIR QUALITY IN SHIMLA

In early 2021, Shimla was experiencing “Moderate” air quality with a US AQI reading of 76. This is in accordance [27] with the World Health Organisation (WHO). In early 2020, the Ambient Air Quality Monitoring Station at Taka Bench on the ridge of Shimla city had been restarted.

The assessment of ambient air quality through this station will give a boost to the tourism sector in the state including Shimla and improve Shimla's ranking under the Smart City program. In addition, online continuous ambient air monitoring stations are being set up in Shimla and Baddi.

Steps that can be taken to improve the air quality in Shimla city:

Major contributor towards air pollution in Shimla is the twenty year old diesel vehicles running on the roads have to be stopped to eliminate air pollution. They are causing the most air pollution.

There is also a need to limit the number of vehicles allowed into the city centre at any given time. Green sites are encouraged as are the planting of native trees to act as a wind-break and help absorb some of the carbon dioxide (CO_2).

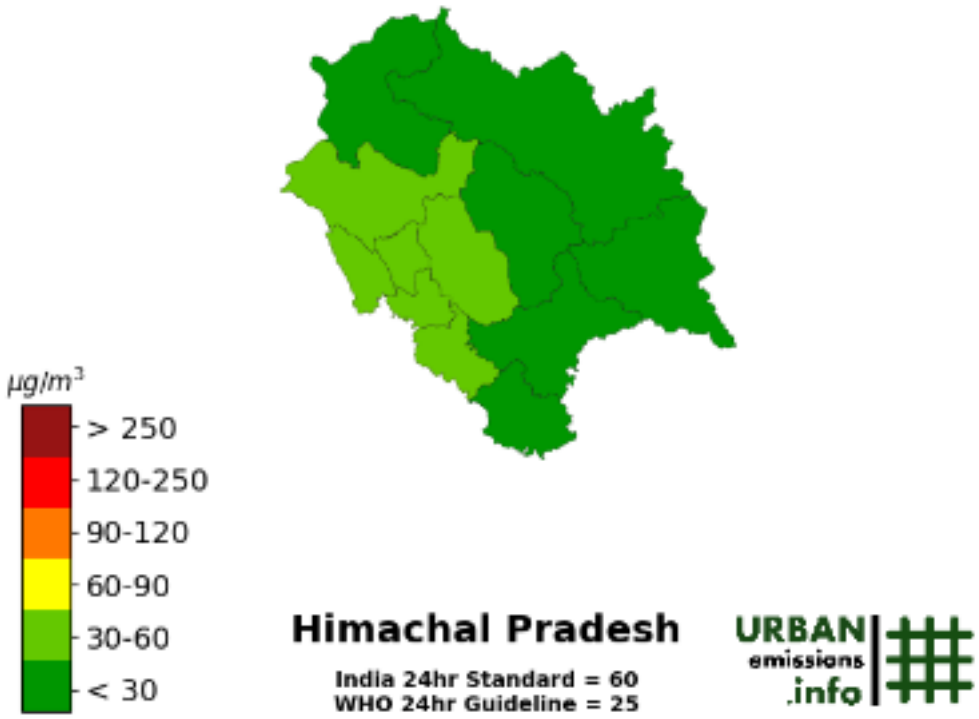

Fig.1.4: Air Quality in Shimla City

1.7 IMPORTANCE OF EMISSIONS IN AIR QUALITY

- Environmental emissions plays a vital role within the unharness of pollutants on air and matrix of soil that has relevancy as a result of it drives a decline of multifariousness. Different factors whether deforestation, air or water pollution, vulnerable animals all are associated with environmental effects.
- Emissions from environment have direct effect on outdoor pollution as well as on air quality inside**.** Hence these external [28] emissions are subject to existence or presence of pollutants in indoor or internal environment.

- The existence of pollutants in our atmosphere depends on emission sources. Also it is important to monitor and control the atmospheric pollution as it is of great importance in public health.
- Hence proper management of emission sources is useful as it can be a way to limit the road transport so that pollution level in environment can be reduced.

1.8 COPERT SOFTWARE

COPERT5 is a software program which is used as a tool to calculate different emissions from the road transport. COPERT5 is used so that the national professionals can develop national annual inventories [4] can calculate emissions from road transport sector. This software follows EU standards and as per that data is collected and vehicle categorisation is done. COPERT relies and hence depends on the mean driving speed and the distance travelled by vehicle.

Features of COPERT Software:

- Calculating emissions from the transport sector.
- Developing an emission inventory.
- Vehicle categorizing on basis of vehicle type, fuel type and standard whit it follows.
- Pollutants includes the following:
    - Air pollutants such as CO, NOx, VOC, PM.
    - Greenhouse gases (CO_2, N_2O, CH_4)

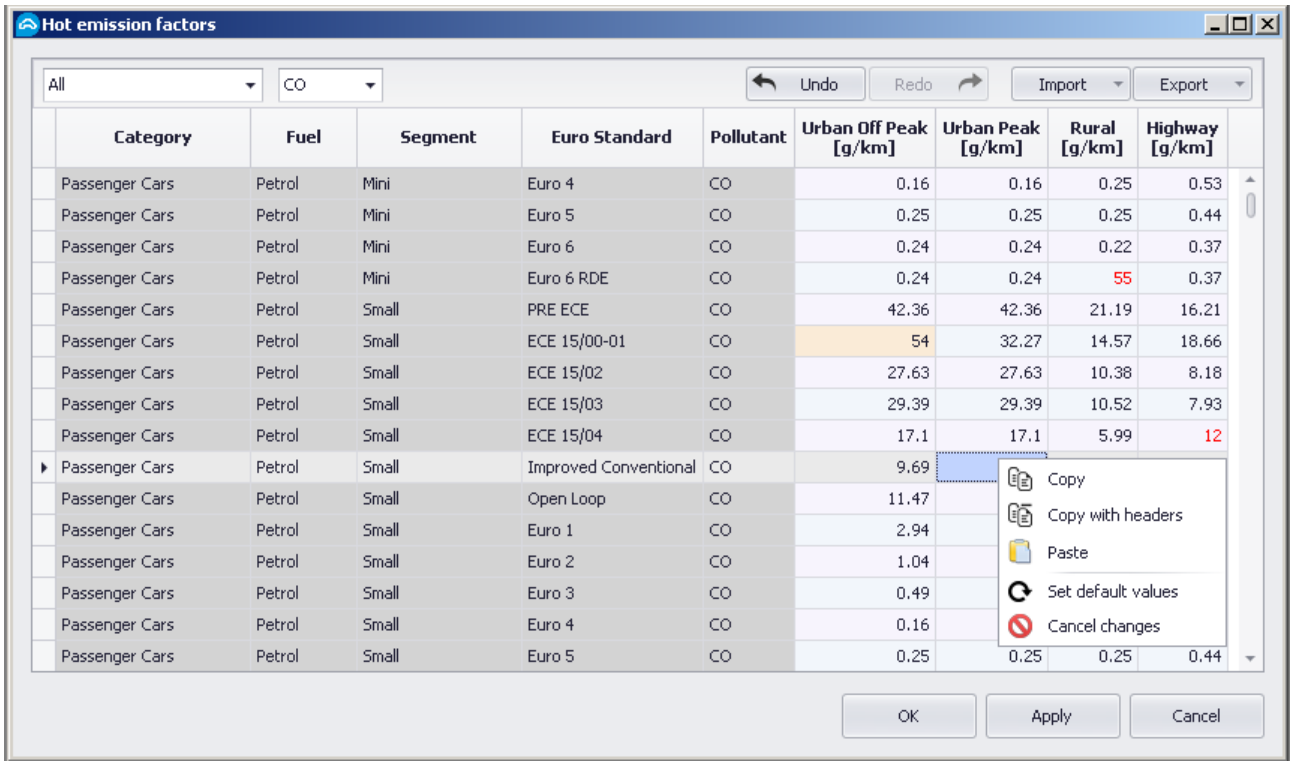

Fig. 1.5: Stock Configuration in COPERT 5 Software

Vehicle categorisation which includes the type of vehicle, category to which that vehicle belongs, fuel type, vehicle segment, the Euro standard to which it belongs are some of the essential requirement needed in order to calculate the emission and thus getting the desired results from the software.

1.9 EUROPEAN EMISSION STANDARDS

In the European Union, nitrogen oxides (NOx), carbon monoxide (CO) and particulate matter (PM) emissions are regulated for most of the vehicle types including trucks, cars, locomotives and similar vehicles. For each vehicle type different standards apply.

COPERT 5 software used in our case follows these EU standards. Till now there are six euro standards.

1.10 INDIAN STANDARDS

Indian Standards are known as Bharat stage emission standards. These are the emission standards followed by the Indian Government to control output of various [29] pollutants from vehicles. The Bharat Stage Standards are based on European norms.

Table 1.1 Euro Norms AND Bharat Stage Norms [30]

Euro Norms	**Date of implementation**	**Bharat Stage Norms**	**Date of implementation**
Euro 1	January 1993	India 2000	Year 2000
Euro 2	January 1997	BS 2	April 2005
Euro 3	January 2001	BS 3	April 2010
Euro 4	January 2006	BS 4	April 2017
Euro 5	January 2011	BS 5	Skipped
Euro 6	September 2015	BS 6	April 2020

EURO 6 vs BS6

There is not [30] much difference in the style of driving in India and Europe. The rules related to vehicles and mean speed is a little different. Hence both do not vary by a huge margin.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

This chapter includes critical analysis of various articles, books and journals about the emission inventory. Different literature has been evaluated, which helped us in understanding different methods and techniques used to calculate development of emission inventory. It also helped us in identifying research gaps and summary of few literatures has been provided below.

S Sunder, T S Panwar [Bangalore City]: -Receptor modelling [3] put forward the concept of using chemical and physical characteristics of matter such as gasses and particles which is measured at source and always present to identify source contribution to receptor concentration. Receptor modelling use dispersion modelling in order to estimate your unwanted emissions present in our environment and to estimate the source apportionment and emissions which effect the surrounding most. Receptor and dispersion modelling have vital part in Bangalore report in order to assess the local conditions.

The chemical mass balance receptor modelling is method used for determining contribution of various volatile compounds such as VOCs and NMOCs which effect the environment most and have been measured in ambient air for the particular city or in a particular airshed area. Because this method is air based so it offers a particular type of check on your emissions inventories that have been developed through traditional permit, survey, emission factors and source test techniques or either using software.

The major focus of this report is to estimate and calculate emissions regarding line source and other sources to keep check on rising trends of air pollutants in atmosphere.

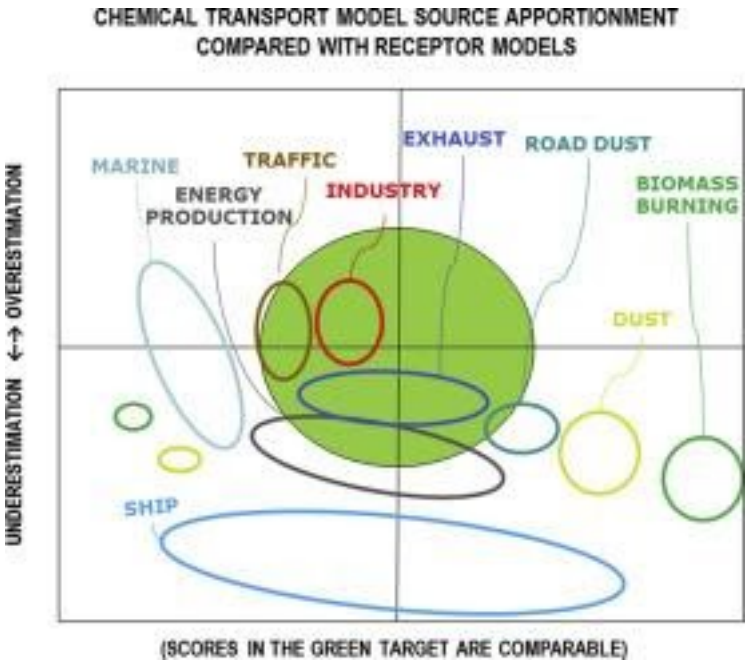

Fig 2.1: Chemical Mass Balance Approach

Prof. S. Pushpavanam [Chennai city]: - After going to this report [2] we have clear idea that this report allows us to determine various variables that effect our environment the most and to have an effective control over our pollutants level in hotspot area of the city. Considering all important facts dispersion model used in order to determine ten points regarding where the pollution level is high in those ten points of the city. The reduction points or conditions were discussed and analysed helping to reduce prevail of pollutants or emissions in the city. At last, all those critical points are analysed throughout the city.

The primary source which contributes more in this report is NOx which come from vehicular exhaust and on road dust re-suspension which is source of PM10. Per capita emissions of these each variable is also being determined across the cities. Pollution or emissions for year 2012 and 2107 have been calculated.

Different methods and techniques have been applied in order to analyse things but some of them were found significant in dealing with these methods. For example, if we take care of

our surrounding environment there will be less air pollution less PM contraction in environment and will give significant reduction in pollutant of NOx.

Anikender Kumar [Delhi city]: - This paper has researched on line sources majorly as vehicular emissions dominate more towards pollution for Delhi [1], capital of India, this report has developed the detailed [18] source emission inventory for the city.th main purpose of this paper is to introduce us to a software or model called as IVE [19] (international Vehicular Emission) model. The major pollutants of emissions such as CO, NO_x and PM concentrations are approximately 509, 195 and 15 tons per day in Delhi and Nowadays AQI in Delhi is around 425 which make it more difficult to live in cities like these. The maximum emission generated in Delhi per day is emission generated by sone cities in country in each year have percentage around 86%, 27 %and 71%.

Vehicles which run or operates on petrol and diesel are primary source for CO and PM. Similarly, CNG vehicles are main contributors of NO_x gasses.

There are various methods which can be used in order to determine vehicular emission. The USEPA [20] mobile model is one of them widely used everywhere which can be used but we neglect this model due to certain factors and conditions which this model is not able to full fill. This model certain driving, temperature and mileage factors are issues which lead to failure of this model in India.

So, we introduced a model which is successful in India that is IVE model [11] and the basic features of this model are as
follows:

The features of IVE model are as follows:

1. Different modes of driving have been introduced.
2. Metrological variation in various situations or conditions.
3. Different pollutants for particular emission with respect to the fuel type vehicle.

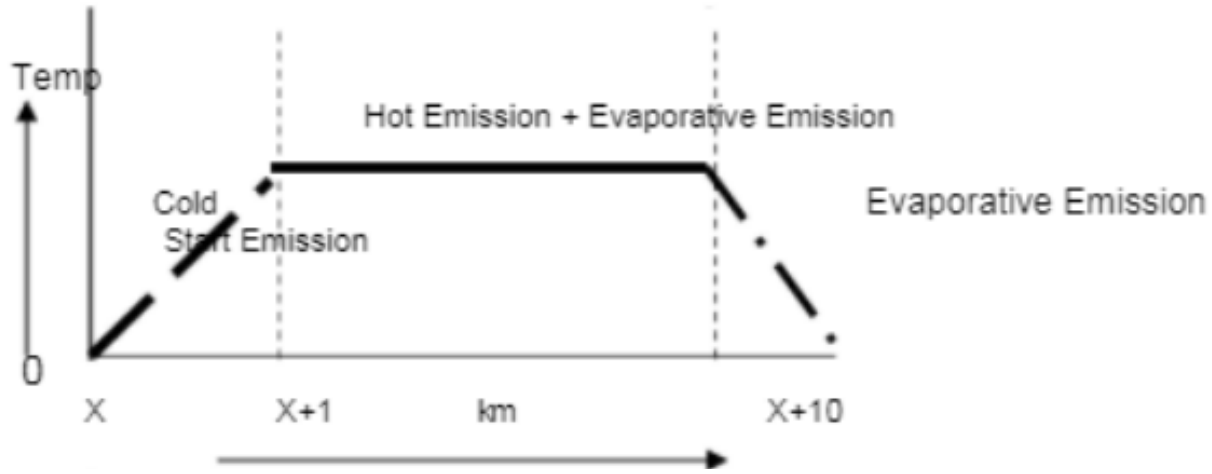

Fig 2.2: Vehicular growth in Delhi [18]

Isaac Dontwi [Ghana]: In this report they [23] have calculated the vehicular emissions using COPERT 3 software which is based on vehicular stock configuration data for the particular city from their respective regional transport board. The software run on data that is based on various factors such as mileage, temperature vehicle population and road condition at respective cities. COPERT 3 makes all work easy and accurate as software is easy to use and apply.

The COPERT allows in calculating vehicular emission and majorly focus on important components such as CO, Pb and CO2 that will link what is happening in Ghana and by using all user-friendly interferences. Other ways and modelling methods can also be used in order to determine the air quality in Ghana but it will take time and includes IVE, US EPA Mobile model, Chemical mass balance all these can be used while discussing this report. But at last, we stick to the easy and faster way to get emissions that is by using COPRT 3.

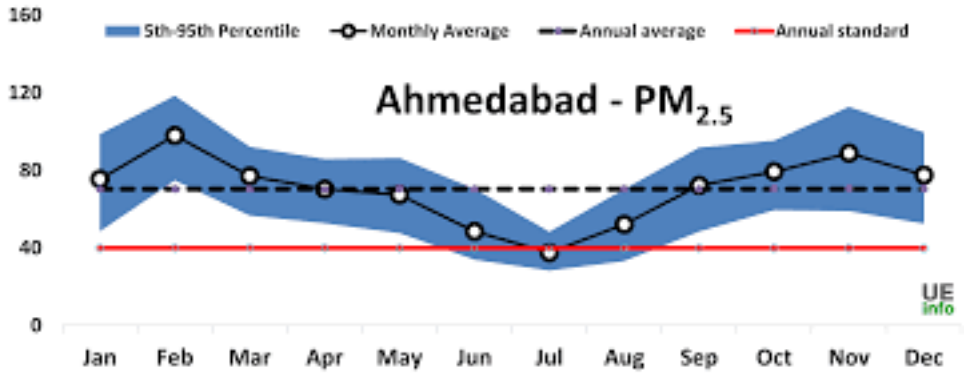

Fig2.3: Vehicle emission stages

G. Beig, Neha S. Prakhi [Ahmedabad city]: This report [6] focuses on all those aspects which will affect our environment adversely and made their contributions towards making emission inventories of CO, NOx, VOCs, SO2, PM2.5, PM10, BC and OC. From all these 2 most important emissions BC and OC are taking place in recent time, and hence we need to work on these 2 emission inventories for the work in report of Ahmedabad city.

To understand the various chemical and physical variation going through city and to assess the pollution level in city [26] Metropolitan Region is selected over a particular hotspot and to get success in this work accurate calculation of emission is required in the report.

While calculating emission inventory various other gadgets and features are added in this report like use of 3-D chemical transport model for the real time estimation of pollutants int the assessing area of survey.

The emission inventory created in this report is accurate due to some factors or methods which allow the model to run properly they may include detailed field survey to collect our primary and secondary data or to adopt method of GIS based which allow to work more accurately in this report and also may give live time tragic flow for each and every road in the city.

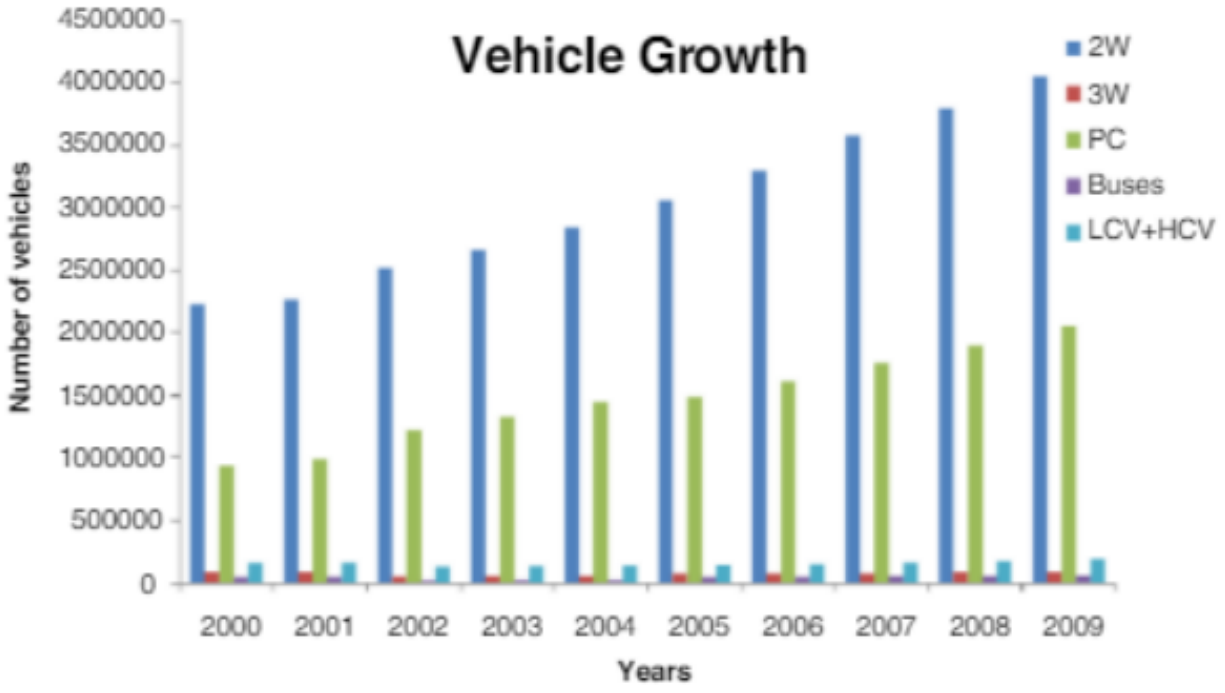

Fig 2.4: - PM concentration in Ahmedabad city [22]

Dr Rakesh Kumar [Mumbai city]: - From this [24] report we can draw a conclusion that ambient air quality maintenance is not at all easy process. Every time Mumbai AQI has shown some unbelievable trends with respect to PM10, SO2 and NO2 between year [00-2005.From past few years PM and NOx concentration seems to be increasing constantly over a period of time and causes high tides in Mumbai beaches. So, all these analyses and quick reviews on city helps to make ambient air quality in Mumbai a place so all these small and big steps can reduce pollution level in cities. These small initiatives will help to improve AQI for cities and will maintain the sustainability.

The Mumbai city need help from urban centres in order to achieve their national goal to keep environment clean and better air quality. Besides all this modelling methods used in this report are:

Chemical Mass Balance which will include results regarding industrial and vehicular zones for that particular strategies have been adopted. From this modelling we conclude that PM concentration is exceeding limits in the city, while other components can be reduced using or adopting these strategies.

For your better air quality dispersion model can also be included with chemical mass balance approach in order to apply these where hotspot places are more predominant. Dispersion model also been used over different scenario from past few years.

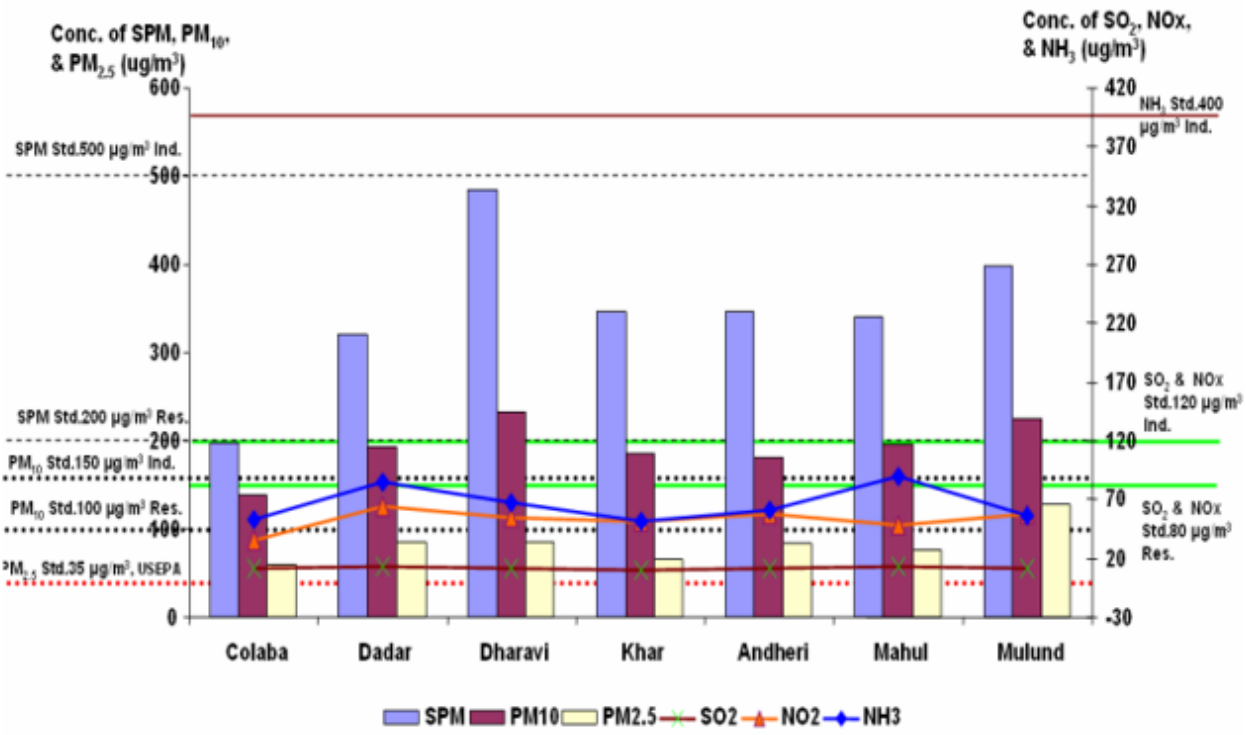

Fig2.5: - Average concentration of Pollutants at Different cities

2.2 RESEARCH GAP

• From the literature most of calculation of vehicular emissions is performed using software mainly IVE model used in Pan India.

• Chemical Mass Balance approach, Dispersion model and Receptor modelling were major modelling part of research papers.

• European software (copert 5) used in our case which give accurate results.

2.3 RESEARCH OBJECTIVES

- To compare the increase in vehicular emission for same city and see trends that how much emissions generation factors have increased in regards with previous years.
- Overall aim of research paper is to understand the various modelling procedures that have been adopted and to know which modelling or software is getting more accuracy, so to assess the condition in report correctly and to assess air pollution distribution with have relative health effect and socio-economics.
- To inventories various pollutants.

CHAPTER 3
METHODOLOGY

3.1 GENERAL

In order to find the total emissions from the transport sector mainly vehicular emissions for Shimla city, we have used European based software called COPERT5. COPERT5 requires lesser input data and gives detailed emission calculation. An inventory of pollutants specifically criteria pollutants CO, VOC, NO_x, and PM has been made for the year 2010,2013 and 2020 using the standard input data we have collected.

3.2 STANDARDISATION OF VEHICLE CATEGORY

After collecting data from the respective Regional Transport Office, we converted vehicular category to European Standards as software which we are using is COPERT5 and is based on European standards.

In European Standards the classifications of vehicle categorisation are based on United Nation Economic Commission for Europe where a clear flow chart is given for all types of vehicle that can be categorised in accordance to its particular Description.

For example:

1. **L category:** includes vehicles having less than four wheels but this may include light vehicles also.

L category is sub categorised as:

L1: Two wheeled vehicle but having engine cylinder not exceeding 50 cm3 and speed of vehicle less than 50 kmph which will include electric bicycle.

L2: Three-wheeler having cylinder capacity less than 50 cm3 but speed not more than 50 kmph example will include auto rikshaw.

L3: Two wheeled vehicle whose engine cylinder capacity exceeds 50cm3 and speed can be more than 50 kmph example include motorcycle.

L4: Special type of vehicle having unsymmetrical arrangement but engine exceeding 50 cm3 and speed more than 50 kmph example will be motorcycle with sidecars.

L5: Special type of vehicle having symmetrical arrangement but exceeding engine cylinder capacity 50 cm3 and speed more than 50 kmph example will include motorized tricycle.

L6: Four vehicle weight not exceeding 350 kg and maximum design speed should not be more than 45km/h and whose engine will not exceed 50 cm3 example will be Golf cart and Mobility scooter.

L7: Four vehicle mass more than 400kg but not that type of L6 but can carry goods also and is a type of microcars and is most effective and interesting in this L category.

2. **M category** will include those vehicles which have at least 4 wheels and can be used for passenger carrying purpose. M category is sub categorised as**:**

M1: Vehicle generally used to carry passenger but not exceeding seats more than 8 including driver this category includes cabs and vans.

M2: Passenger carrying vehicle having seating capacity 8 adding driver seat and having maximum weight not exceeding 5 tonnes generally includes mini bus.

M3: vehicle carry passenger having seating capacity more than 8 and having maximum weight more than 5 tonnes include bus.

3. **N category:** includes vehicles having four wheels used for carrying goods and are much more powerful than normal vehicles.

N category is sub categorised as:

N1: Vehicle that can be used for carrying goods but self-weight of vehicle should not exclude 3.5 tonnes example will include pickup trucks and van.

N2: Vehicle used to carry goods but their self-weight should be between 3.5 to 12 tonnes example will include trucks.

N3: Vehicles having weight more than 12 tonnes and been used to carry goods example will include commercial trucks.

4. **O category** includes trailers which further includes semi-trailers in this category.

O category is sub categorized as:

O1: Trailers whose weight will not exceeds 0.75 tonnes.

O2: Trailers whose self weight will not 3.5 tonnes and will remain between 0.75 to 3.5 tonnes.

O3: Trailers whose weight remain between 3.5 to 10 tonnes

O4: Trailers whose weight exceeds 10 tonnes.

5. Special Type of Vehicle which includes Motor caravan, Camper van, Motorhome, Armor car (VIP), Ambulance, Hearse.

After discussing the categorisation part above, we come to the stock configuration in COPERT which is mainly vehicle categorisation. Here firstly we need to decide which vehicle will go in the category of Passenger car, Light commercial, Heavy duty, busses or in L-category. After that we will check fuel type on which your vehicle operates on and under this we have petrol, diesel, hybrid, gasoline and CNG.

Then we check for the segment of the vehicle that may fall in, assume the vehicle falls in the passenger car then segment is mini, small, medium and Large SUV Executive.If vehicles fall in Light Commercial segment, then category will be N1-1, N2-2 and N3-3.If a vehicle falls in Heavy Duty segment, then it may fall in Rigid or in Articulated segment but based on weight in tones.If vehicles fall in Busses, then segments will be urban coaches, coaches' standards, coaches articulated etc.If vehicles fall in L-category, then segment will be mopeds 4 stroke, mopeds 2 stroke, Quads and ATVs and at last micro cars.

The tables for the vehicle categorisation is in the section 3.3.under stock data.

3.3 INPUT DATA

The data necessary for calculating the amount of pollutants emitted by different categories of vehicles are:

i. **Properties**- It is used to describe the study domain's properties and includes environmental information and trip characteristics.

a. *Environmental information:* We have provided maximum and minimum monthly temperature and average monthly humidity for Shimla using world weather online website. For the year 2010, following environmental information has been obtained;

Table 3.1 Environmental information for Shimla 2010 (Source: worldweatheronline.com)

Month	Minimum temperature	Maximum temperature	Humidity
January	6	16	30
February	7	17	44
March	13	25	30
April	17	30	21
May	19	32	26
June	20	32	30
July	19	27	78
August	18	25	91
September	15	22	86
October	10	22	66
November	7	20	51
December	3	16	41

Table 3.2 Environmental information for Shimla 2013 (Source: worldweatheronline.com)

Month	Minimum temperature	Maximum temperature	Humidity
January	0	15	46
February	3	16	63
March	7	23	47
April	10	27	43
May	14	31	29
June	17	28	59
July	17	27	78
August	16	25	89
September	13	25	75
October	11	24	65
November	5	20	40
December	2	17	44

Table 3.3 Environmental information for Shimla 2020 (Source: worldweatheronline.com)

Month	Minimum temperature	Maximum temperature	Humidity
January	2	12	65
February	4	17	51
March	7	19	62
April	11	25	50
May	15	29	42
June	18	29	45
July	19	29	66
August	18	27	84
September	16	27	69
October	13	27	44
November	8	20	46
December	6	18	41

b. Trip characteristics: It defines the study area's average trip length in km and trip duration in hours. We have provided 20km trip length and 0.5 hours trip duration for Shimla city.

ii. Fuel- Fuel and the lubricant specifications are already given in the software. It is listed as different grades of fuels and lubricants with their compositions in a tabular form. So we applied the specs to our inventory.

iii. Vehicle- It describes the fleet composition and behaviour of the current run. Under this, we have to input following data;

a. Stock configuration: We had to select which types of vehicle was in fleet for the year 2010 in Shimla. However, the categorisation of vehicles we follow in India is not same as that used in COPERT5 which is EU categorisation. So we had to categorise the vehicles as per the COPERT5 stock configuration. The following categories are as per COPERT5;

• PCs

• Light commercial vehicles

• Heavy Duty Vehicles

• Buses

• Two Wheelers

These categories are subdivided into further segments. Passenger cars are divided into gasoline fuelled ones, which farther is categorised into three capacity classes, diesel cars are of two capacity classes. Vans and small trucks fall under light duty vehicles which is specified as diesel and gasoline fuelled vehicles. HDTs have 15 sub-categories in total. These are specified according to type of vehicle (rigid or articulated), the fuel (gasoline, diesel) and ross weight(>3,5 t to 60 t). Busses are of different weight classes. Lastly two-wheelers are classified as mopeds (<50cc) and other three subcategories of motorcycles.

b. *Stock and activity data:* We had to input how many numbers of each type of vehicles was there in Shimla for the year 2010,2013 and 2020 and correspondingly each mean activity (km/year) and lifetime cumulative activity (km). We got vehicle count data from RTO Shimla.

Table 3.4 Vehicle categorisation and count as per COPERT5 model for 2010

EU categorisation	**Fuel**	**Segment**	**EURO standards**	**Vehicle (Shimla)**	**Vehicle count**	**EU count(n)**
Buses	Diesel	Urban midi	IV	Buses	562	
Buses	Diesel	Urban midi	IV	Omni bus (Pvt.)	112	
Buses	Diesel	Urban midi	IV	Mini bus	263	937
Buses	Diesel	Coaches automated	IV	Deluxe/ Semi deluxe bus	15	15
Buses	Diesel	Coaches standard	IV	Omni bus	134	134
HDT	Diesel	Artc 40-50t	IV	Haulage vehicle	3	
HDT	Diesel	Artc 40-50t	IV	Excavator	9	12
HDT	Diesel	Rgd >32t	IV	Dumper	18	
HDT	Diesel	Rgd >32t	IV	Multi axle goods vehicle	7	25
HDT	Diesel	Rgd 20-28t	IV	Crane	10	10
HDT	Diesel	Artc 20-28t	IV	Tractors	165	165
HDT	Diesel	Artc 34-40t	IV	Earth moving equipments	108	108

HDT	Diesel	Rgd 12-14t	IV	Goods Truck container	1	1
HDT	Diesel	Rgd 14-20t	IV	Heavy goods vehicles	2288	2288
HDT	Diesel	Rgd<=7,5t	IV	Medium goods vehicles	885	885
HDT	Diesel	Rgd 7,5-12t	IV	Road water sprinklers	9	
HDT	Diesel	Rgd 7,5-12t	IV	Tankers	11	20
Passenger cars	Diesel	Medium	IV	Ambulance	45	45
Passenger cars	Diesel	Large SUV executive	IV	Camper van	7	
Passenger cars	Diesel	Large SUV executive	IV	Jeep Taxi	37	
Passenger cars	Diesel	Large SUV executive	IV	Passenger and goods vehicle	10	54
Passenger cars	Petrol	small	IV	LMV (Cars)	24329	
Passenger cars	petrol	small	IV	Heers cars(HMV)	107	
Passenger cars	petrol	Small	IV	PSV motor cab	40	24476
Passenger cars	petrol	Small	III	Motor cab/car taxi	8073	8073
Passenger cars	Petrol	Mini	IV	LMV (IMP and Van)	701	701
Passenger cars	Petrol	SUV executive	IV	LMV(Jeep/Gypsy)	1277	1277
Passenger cars	Petrol	Medium	IV	Maxi cab	3189	
Passenger cars	petrol	Medium	IV	Station wagon	2	3191
LCVs	petrol	N1-II	IV	Light goods vehicle	4131	4131
LCVs	Diesel	N1-III	IV	Tow truck	1	1
L-category	petrol	Mpds 2 stroke	IV	Scooter/ moped	4353	
L-category	petrol	Mpds 2-stroke	IV	Moped	44	4397
L-category	petrol	Mpds 2 stroke	III	Scooter with side car	11	11
L-category	petrol	mtcs 4-stroke	III	Motor cycle	5265	5265
L-category	petrol	mtcs 4-stroke	IV	Motor cycle (IMP)	62	
L-category	petrol	mtcs 4-stroke	IV	Motor cycle with side car	11	73
L category	Diesel	Micro car	IV	Three wheeler (goods)	7	
L-category	Diesel	Micro car	IV	Three wheeler private	154	161

Table 3.5 Vehicle categorisation and count as per COPERT5 model for 2013

EU categorisation	Fuel	Segment	EURO standards	Vehicle (Shimla)	Vehicle count	EU count(n)
Buses	Diesel	Coaches automated	IV	Air conditioned bus	2	
Buses	Diesel	Urban midi	IV	Buses	1421	
Buses	Diesel	Urban midi	IV	Omni bus (Pvt.)	110	
Buses	Diesel	Urban midi	IV	Mini bus	420	1951
Buses	Diesel	Coaches automated	IV	Deluxe/ Semi deluxe bus	15	15
Buses	Diesel	Coaches standard	IV	Omni bus	187	187
Buses	Diesel	Urban buses standard	V	Tourist bus	21	21
HDT	Diesel	Artc 40-50t	IV	Articulated vehicles	1	
HDT	Diesel	Artc 40-50t	IV	Haulage vehicle	27	
HDT	Diesel	Artc 40-50t	IV	Excavator	17	45
HDT	Diesel	Rgd >32t	IV	Dumper	28	
HDT	Diesel	Rgd >32t	IV	Multi axle goods vehicle	8	
HDT	Diesel	Rgd >32t	IV	Bulldozer	2	38
HDT	Diesel	Rgd 20-28t	IV	Crane	19	19
HDT	Diesel	Artc 20-28t	IV	Tractors	284	284
HDT	Diesel	Artc 34-40t	IV	Earth moving equipments	262	262
HDT	Diesel	Rgd 12-14t	IV	Goods Truck container	8	
HDT	Diesel	Rgd 12-14t	IV	Fire fighter	6	
HDT	Diesel	Rgd 12-14t	IV	Self loader concrete mixer	2	
HDT	Diesel	Rgd 12-14t	IV	Tower wegons	1	17
HDT	Diesel	Rgd 14-20t	IV	Heavy goods vehicles	7093	
HDT	Diesel	Rgd 14-20t	IV	Vehicle fitted with generator	0	
HDT	Diesel	Rgd 14-20t	IV	Vehicle fitted with drilling rigs	1	7094
HDT	Diesel	Rgd<=7,5t	IV	Medium goods vehicles	2347	2347
HDT	Diesel	Rgd<=7,5t	V	Fork lift	0	
HDT	Diesel	Rgd<=7,5t	V	Transient mixer	26	26
HDT	Diesel	Rgd 7,5-12t	IV	Road water sprinklers	1	
HDT	Diesel	Rgd 7,5-12t	IV	Tankers	38	
HDT	Diesel	Rgd 7,5-12t	IV	Explosive van	5	
HDT	Diesel	Rgd 7,5-12t	IV	Road roller	0	44
HDT	Diesel	Artc 34-40t	IV	Trailers	0	0
PCs	Diesel	Medium	IV	Ambulance	188	

PCs	Diesel	Medium	IV	Mobile lab van(HMV)	1	189
PCs	Diesel	Large SUV executive	IV	Camper van	13	
PCs	Diesel	Large SUV executive	IV	Jeep Taxi	87	
PCs	Diesel	Large SUV executive	IV	Passenger and goods vehicle	18	118
PCs	Petrol	small	IV	LMV (Cars)	43596	
PCs	petrol	small	IV	Heers cars(HMV)	103	
PCs	petrol	Small	IV	PSV motor cab	100	
PCs	petrol	Small	IV	Mobile lab Van(LMV)	0	43799
PCs	petrol	Small	III	Motor cab/car taxi	9934	9934
PCs	Petrol	Mini	IV	LMV (IMP and Van)	967	
PCs	Petrol	Mini	IV	Heers cars(LMV)	13	980
PCs	Petrol	SUV executive	IV	LMV(Jeep/Gypsy)	2233	2233
PCs	Petrol	Medium	IV	Maxi cab	3491	
PCs	petrol	Medium	IV	Station wagon	2	
PCs	petrol	Medium	IV	Radio Taxi	2	3495
PCs	petrol	Medium	V	Tourist motor cab/ taxi	13	13
LCVs	petrol	N1-II	IV	Utility Van	23	23
LCVs	Diesel	N1-III	IV	Tow truck	13	
LCVs	Diesel	N1-III	IV	Recovery Van(heavy)	16	29
LCVs	Diesel	N1-III	V	X-ray van	4	4
LCVs	Diesel	N1-III	III	Break down van	1	1
LCVs	Diesel	N1-III	V	Mobile clinic	0	0
LCVs	Diesel	N1-I	IV	Postal van	1	
LCVs	Diesel	N1-I	IV	Recovery van(light)	24	25
LCVs	Diesel	N1-II	IV	Cash van	1	1
LCVs	Diesel	N1-II	IV	Delivery van	7	
LCVs	Diesel	N1-II	IV	Light goods vehicle	8076	
LCVs	Diesel	N1-II	IV	Mobile library van	0	
LCVs	Diesel	N1-II	IV	Mobile service van	0	
LCVs	Diesel	N1-II	IV	Mobile workshop van	0	
LCVs	Diesel	N1-II	IV	Recovery Van(medium)	5	8088
LCVs	Diesel	N1-II	V	Mobile canteen	1	1
L-category	petrol	Mpds 2 stroke	IV	Scooter/ moped	5563	
L-category	petrol	Mpds 2-stroke	IV	Moped	109	5672
L-category	petrol	Mpds 2 stroke	III	Scooter with side car	254	254

L-category	petrol	mtcs 4-stroke	III	Motor cycle	9995	9995
L-category	petrol	mtcs 4-stroke	IV	Motor cycle (IMP)	76	
L-category	petrol	mtcs 4-stroke	IV	Motor cycle with side car	12	88
L-category	Diesel	Micro car	IV	Three wheeler (goods)	11	
L-category	Diesel	Micro car	IV	Three wheeler (passenger)	329	340
L-category	Diesel	Micro car	III	Invalid carriage	14	14
L-category	petrol	Quad and ATVs	IV	Three wheeler (private)	3	3

Table 3.6 Vehicle categorisation and count as per COPERT5 model for 2020

EU categorisation	**Fuel**	**Segment**	**EURO standards**	**Vehicle (Shimla)**	**Vehicle count**	**EU count(n)**
Buses	Diesel	Urban midi	V	Buses	2152	
Buses	Diesel	Urban midi	V	Omni bus (Pvt.)	115	
Buses	Diesel	Urban midi	V	Omni bus	244	
Buses	Diesel	Urban midi	V	Educational institute bus	11	2522
HDT	Diesel	Artc 40-50t	V	Articulated vehicles	1	
HDT	Diesel	Artc 40-50t	V	Excavator	66	67
HDT	Diesel	Rgd >32t	V	Dumper	12	
HDT	Diesel	Rgd >32t	V	Earth moving equipments	534	
HDT	Diesel	Rgd >32t	V	Bulldozer	2	548
HDT	Diesel	Rgd 20-28t	V	Crane mounted vehicle	65	65
HDT	Diesel	Artc 20-28t	IV	Tractors	407	407
HDT	Diesel	Rgd 12-14t	V	Fire fighter	23	23
HDT	Diesel	Rgd 12-14t	IV	Vehicle fitted with rig	1	1
HDT	Diesel	Rgd 14-20t	V	Heavy goods vehicles	23399	23399
HDT	Diesel	Rgd 14-20t	V	Construction equipment vehicle	195	195
PCs	Diesel	Medium	V	Ambulance	525	
PCs	Diesel	Medium	V	Motor car	104281	104806
PCs	Diesel	Large SUV executive	V	Camper van	4	4
PCs	petrol	Small	V	Adapted vehicle	11	11
PCs	petrol	Small	IV	Motor cab/car taxi	11228	11228
PCs	Petrol	Medium	V	Maxi cab	3499	3499
PCs	petrol	Medium	VI	Pvt service vehicle	537	537
LCVs	petrol	N1-II	V	Hearses	94	94

LCVs	Diesel	N1-III	V	Tow truck	12	
LCVs	Diesel	N1-III	V	Recovery Van(heavy)	132	144
LCVs	Diesel	N1-III	V	X-ray van	4	
LCVs	Diesel	N1-III	V	Break down van	1	
LCVs	Diesel	N1-III	V	Mobile clinic	1	6
LCVs	Diesel	N1-II	V	Cash van	1	
LCVs	Diesel	N1-II	V	Mobile canteen	3	4
L-category	petrol	Mpds 2-stroke	IV	Moped	1606	
L-category	petrol	Mpds 2 stroke	IV	Scooter with side car	264	1870
L-category	petrol	mtcs 4-stroke	V	Motorised cycle	66	66
L-category	petrol	mtcs 4-stroke	IV	Scooter/Motor cycle	29447	29447
L-category	Diesel	Micro car	IV	Three wheeler (goods)	14	
L-category	Diesel	Micro car	IV	Three wheeler (passenger)	282	296

Table 3.7 Sample mean activity data

Category	Fuel	Segment	Euro Standard	Mean activity
PCs	Petrol	Mini	Euro 4	5,000.0
PCs	Petrol	Small	Euro 3	10,000.0
PCs	Petrol	Small	Euro 4	10,000.0
PCs	Petrol	Medium	Euro 4	10,000.0
PCs	Petrol	Large-SUV-Executive	Euro 4	10,000.0
PCs	Diesel	Medium	Euro 4	15,000.0
PCs	Diesel	Large-SUV-Executive	Euro 4	15,000.0
LCVs	Petrol	N1-II	Euro 4	15,000.0
LCVs	Diesel	N1-III	Euro 4	15,000.0
HDT	Diesel	Rgd <=7,5 t	Euro IV	20,000.0
HDT	Diesel	Rgd 7,5 - 12 t	Euro IV	20,000.0
HDT	Diesel	Rgd 12 - 14 t	Euro IV	20,000.0
HDT	Diesel	Rgd 14 - 20 t	Euro IV	20,000.0
HDT	Diesel	Rgd 20 - 26 t	Euro IV	20,000.0
HDT	Diesel	Rgd 26 - 28 t	Euro IV	20,000.0
HDT	Diesel	Rgd >32 t	Euro IV	20,000.0
HDT	Diesel	Artc 20 - 28 t	Euro IV	20,000.0
HDT	Diesel	Artc 34 - 40 t	Euro IV	20,000.0
HDT	Diesel	Artc 40 - 50 t	Euro IV	20,000.0
HDT	Diesel	Artc 50 - 60 t	Euro IV	20,000.0
Buses	Diesel	Urban Midi	Euro IV	25,000.0
Buses	Diesel	Coaches Standard	Euro IV	25,000.0
Buses	Diesel	Coaches Articulated	Euro IV	25,000.0
L-Category	Petrol	Mpds 2-stroke	Euro 3	4,000.0
L-Category	Petrol	Mpds 2-stroke	Euro 4	4,000.0
L-Category	Petrol	mtcs 4-stroke	Euro 3	4,000.0
L-Category	Petrol	mtcs 4-stroke	Euro 4	4,000.0
L-Category	Diesel	Micro-car	Euro 4	4,000.0

c. Circulation data: We fed the average speed and the mileage percentage driven by each vehicle technology per driving mode. In doing all those firstly we have standardised the data and made it ready to be fed in COPERT5.

Table 3.8 Sample mean speed data

Category	Fuel	Segment	EURO	Urban peak	Rural	Highway
PCs	Petrol	Mini	Euro 4	40.0	50.0	80.0
PCs	Petrol	Small	Euro 3	40.0	50.0	80.0
PCs	Petrol	Small	Euro 4	40.0	50.0	80.0
PCs	Petrol	Medium	Euro 4	40.0	50.0	80.0
PCs	Petrol	Large-SUV-Executive	Euro 4	40.0	50.0	80.0
PCs	Diesel	Medium	Euro 4	40.0	50.0	80.0
PCs	Diesel	Large-SUV-Executive	Euro 4	40.0	50.0	80.0
LCVs	Petrol	N1-II	Euro 4	40.0	50.0	80.0
LCVs	Diesel	N1-III	Euro 4	40.0	50.0	80.0
HDT	Diesel	Rgd <=7,5 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Rgd 7,5 - 12 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Rgd 12 - 14 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Rgd 14 - 20 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Rgd 20 - 26 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Rgd 26 - 28 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Rgd >32 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Artc 20 - 28 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Artc 34 - 40 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Artc 40 - 50 t	Euro IV	40.0	50.0	80.0
HDT	Diesel	Artc 50 - 60 t	Euro IV	40.0	50.0	80.0
Buses	Diesel	Urban Midi	Euro IV	40.0	50.0	80.0
Buses	Diesel	Coaches Standard	Euro IV	40.0	50.0	80.0
Buses	Diesel	Coaches Articulated	Euro IV	40.0	50.0	80.0
L-Category	Petrol	Mpds 2-stroke	Euro 3	40.0	50.0	80.0
L-Category	Petrol	Mpds 2-stroke	Euro 4	40.0	50.0	80.0
L-Category	Petrol	mtcs 4-stroke	Euro 3	40.0	50.0	80.0
L-Category	Petrol	mtcs 4-stroke	Euro 4	40.0	50.0	80.0
L-Category	Diesel	Micro-car	Euro 4	40.0	50.0	80.0

d. Fuel evaporation data: The input data like fuel tank size, percentage of vehicles equipped with evaporation control and the distribution of evaporative emissions to different driving modes is software generated. We only have to apply it for our current run.

e. Driving conditions: Here we have given a 0% mean gradient class of road because we don't want to make changes to the baseline emission factor. This slope percentage is required for calculation of hot emission factors.

f. Axles number: This is also software generated and we can use it directly for our calculations.

3.4 CATEGORISATION OF VEHICLE COUNT

The vehicle count for the year 2010, 2013 and 2020 for Shimla city has been filtered out depending on the type of fuel used. This classification has major implications on reading the result. The type of fuel used by the vehicle and the vehicle count has direct impact on quantity of particular type of emission emitted. For example, petrol engines are found to emit more CO and NO_x.

We can see that more the number of vehicles running on each type of fuel, the greater the amount of emissions associated with the kind of fuel used. With this purpose in mind, we have categorised the vehicles as per the fuels running the engine. These tables showing the fuel based vehicle counts will finally help us sort the emissions from transport sector.

Table 3.9 Fuel based vehicle count for year 2010

Category	Vehicle count		Total Vehicle count
	Gasoline Fuelled	Diesel Fuelled	
Passenger Cars	37718	99	37817
Light Commercial Vehicles	1	4131	4132
Heavy Duty Trucks	0	3514	3514
Buses	0	524	524
L-Category	9746	234	9980
Total Vehicles (2013)			55967

Table 3.10 Fuel based vehicle count for year 2013

Category	Vehicle count		Total Vehicle count
	Gasoline Fuelled	Diesel Fuelled	
Passenger Cars	60454	307	60761
Light Commercial Vehicles	23	8149	8172
Heavy Duty Trucks	0	10176	10176
Buses	0	2174	2174
L-Category	16012	354	16366
Total Vehicles (2013)			97649

Table 3.11 Fuel based vehicle count for year 2020

Category	Vehicle count		Total Vehicle count
	Gasoline Fuelled	Diesel Fuelled	
Passenger Cars	15369	104810	120179
Light Commercial Vehicles	0	154	154
Heavy Duty Trucks	0	24705	24705
Buses	0	2522	2522
L-Category	31383	296	31679
Total Vehicles (2013)			179239

CHAPTER 4
RESULTS

4.1 GENERAL

Here we will show and discuss the results we got after feeding all the necessary input data and applying those software generated input depending on our need. It is the vehicular emission inventory of Shimla city for the year 2010. We will discuss the inferences drawn from the result we got.

4.2 RESULTS

4.2.1 Emission factor

The main part of our project is finding the total emissions and the emission factors. We have total emissions in section 4.2.2 and here we will show a sample of emission factors which we got from 2010 data. Since we draw the main conclusions from the total emissions data, we didn't add emission factors of all years which we focused. It helps in knowing the performance of a vehicle and hence is dependent on the vehicle operation.

We generally see two diversifications in emission factor like hot emission factors and cold emission factors. However, the cold emission factors are dependent on monthly temperature of the place and hence to show the factors here will take so many pages. The table below shows the sample emission factors we get after giving all the inputs and running the COPERT5 software. These are the multiplying factors which which take into account the number of vehicles under each category and finally give the amount of emissions generated.

Table 4.1 Hot emission factors for criteria pollutants

Category	Fuel	Segment	Euro Standard	Hot_CO [g/km]	Hot_NO_x [g/km]	Hot_VOC [g/km]	Hot_PM [g/km]
PCs	Petrol	Mini	4	0.9	0.2	0.1	0.1
PCs	Petrol	Small	3	2.3	0.3	0.1	0.1
PCs	Petrol	Small	4	0.9	0.2	0.1	0.1
PCs	Petrol	Medium	4	0.9	0.2	0.1	0.1
PCs	Petrol	Large-SUV-Executive	4	0.9	0.2	0.1	0.1
PCs	Diesel	Medium	4	0.3	2.0	0.0	0.1
PCs	Diesel	Large-SUV-Executive	4	0.3	2.0	0.0	0.1
LCVs	Petrol	N1-II	4	3.3	0.2	0.0	0.0

LCVs	Diesel	N1-III	4	1.0	2.9	0.1	0.1
HDT	Diesel	Rgd <=7,5 t	4	1.2	6.7	0.1	0.1
HDT	Diesel	Rgd 7,5 - 12 t	4	1.8	10.3	0.1	0.1
HDT	Diesel	Rgd 12 - 14 t	4	2.0	11.6	0.1	0.1
HDT	Diesel	Rgd 14 - 20 t	4	2.7	14.5	0.1	0.1
HDT	Diesel	Rgd 20 - 26 t	4	3.3	18.1	0.2	0.1
HDT	Diesel	Rgd 26 - 28 t	4	3.4	18.5	0.2	0.1
HDT	Diesel	Rgd >32 t	4	3.8	21.9	0.2	0.2
HDT	Diesel	Artc 20 - 28 t	4	3.2	18.0	0.2	0.1
HDT	Diesel	Artc 34 - 40 t	4	3.8	22.0	0.2	0.2
HDT	Diesel	Artc 40 - 50 t	4	4.0	24.3	0.2	0.2
HDT	Diesel	Artc 50 - 60 t	4	4.7	29.1	0.3	0.2
Buses	Diesel	Urban Midi	4	2.2	12.5	0.1	0.1
Buses	Diesel	Coaches Standard	4	3.8	18.8	0.2	0.2
Buses	Diesel	Coaches Articulated	4	4.1	21.2	0.2	0.2
L-Category	Petrol	Mpds 2-stroke	3	7.0	0.7	7.1	0.1
L-Category	Petrol	Mpds 2-stroke	4	7.2	0.7	7.2	0.1
L-Category	Petrol	mtcs 4-stroke	3	1.5	0.2	0.6	0.1
L-Category	Petrol	mtcs 4-stroke	4	0.7	0.1	0.2	0.1
L-Category	Diesel	Micro-car	4	3.7	2.8	0.5	0.3

4.2.2 Total emissions

Since criteria pollutants are the major source of air pollution from road transport sector, we have focused mainly on CO, NO_x, VOC and $PM_{2.5}$. We have developed vehicular emission inventory of criteria pollutants CO, NO_x, VOC and $PM_{2.5}$ in the year 2010 over the Shimla city. We have seen 372.9 tons emissions of Carbon Monoxide (CO), 358 tons of Nitrogen Oxides (NOx), 108.3 tons of Volatile Organic Compounds(VOC) and 30 tons of Particulate Matter (PM) in the year 2010.

We have seen 881.8 tons emissions of Carbon Monoxide (CO), 964.3 tons of Nitrogen Oxides (NOx), 197.9 tons of Volatile Organic Compounds(VOC) and 34.2 tons of Particulate Matter (PM) in the year 2013.

We have seen 760.4 tons emissions of Carbon Monoxide (CO), 2004.1 tons of Nitrogen Oxides (NOx), 49.2 tons of Volatile Organic Compounds(VOC) and 56.2 tons of Particulate Matter (PM) in the year 2020. The petrol fuelled vehicles are seen to produce more CO and NO_x and PM are majorly contributed by diesel fuelled engines.

Table 4.2 Total emissions for Shimla city for 2010

Category	CO[t]	NO_x[t]	VOC[t]	PM2.5[t]
Passenger Cars	219.9	223.9	62.9	2.9
Light Commercial Vehicles	76.8	87	3.9	1.2
Heavy Duty Trucks	20.1	22.4	1.9	21.2
Buses	15.5	20	0.9	4
L-Category	40.6	4.7	38.7	0.7
Total emissions	372.9	358	108.3	30

Table 4.3 Total emissions for Shimla city for 2013

Category	CO[t]	NO_x[t]	VOC[t]	PM2.5[t]
Passenger Cars	616.4	45.7	132.6	8.6
Light Commercial Vehicles	35.1	91.4	3.9	5.9
Heavy Duty Trucks	116.8	649.1	6.5	14.6
Buses	30.5	170.5	2	4
L-Category	83	7.6	52.9	1.1
Total emissions	881.8	964.3	197.9	34.2

Table 4.4 Total emissions for Shimla city for 2020

Category	CO[t]	NO_x[t]	VOC[t]	PM2.5[t]
Passenger Cars	76.9	267.4	5.7	9.1
Light Commercial Vehicles	1	1.8	1.1	1
Heavy Duty Trucks	510.5	1568.7	17.1	39.7
Buses	55.7	160.1	1.8	4.9
L-Category	116.3	6.1	23.5	1.5
Total emissions	760.4	2004.1	49.2	56.2

4.2.3 Criteria pollutants emission distribution

The following pie charts will show the percentage of criteria pollutants contributed by each type of vehicles. These percentage is majorly affected by the number of each type of vehicles and the fuel used to run the engine. It is clear that passenger cars major contribute the emissions of CO, NO_x and VOC whereas heavy duty trucks emit huge amount of $PM_{2.5}$.

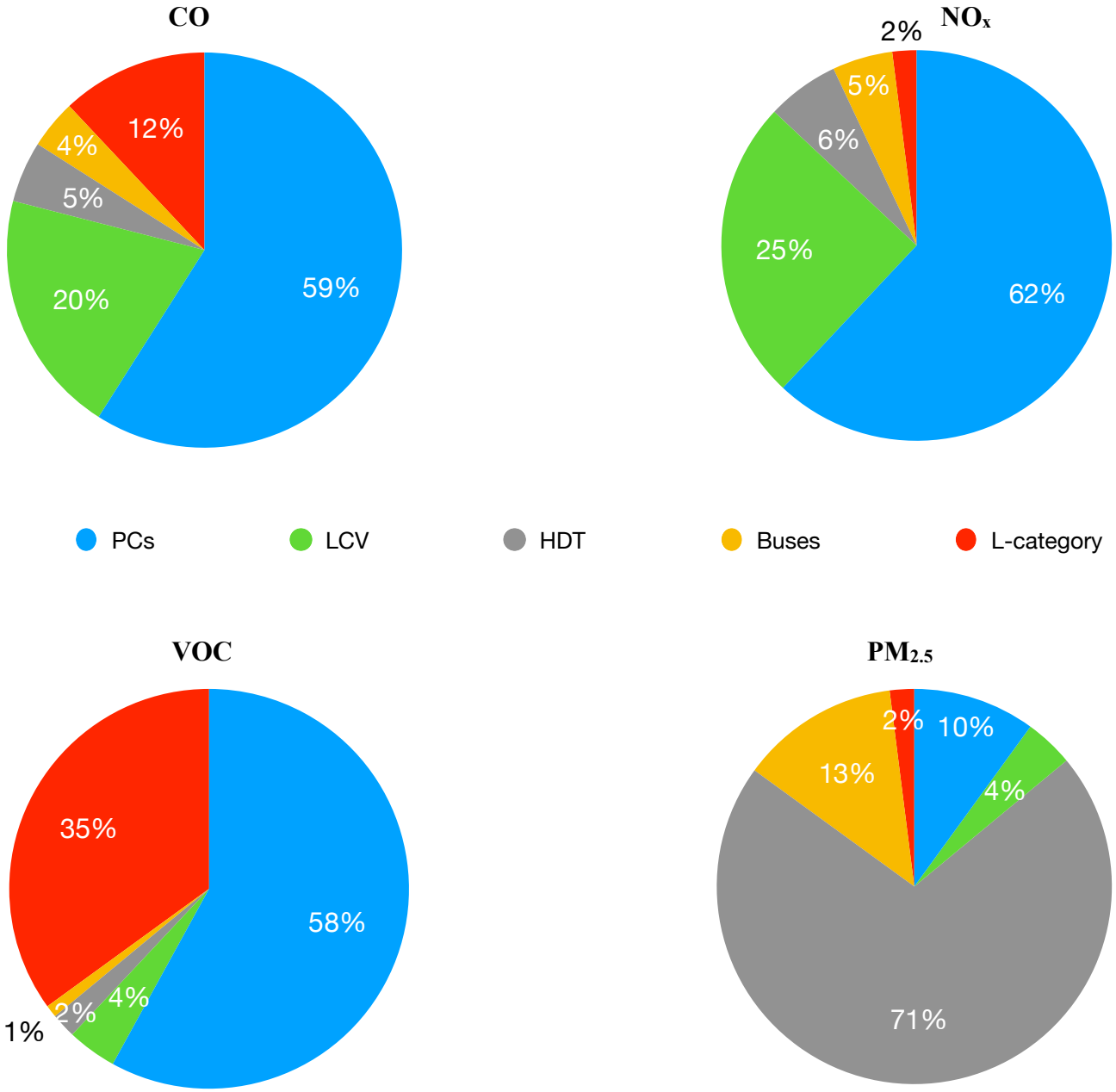

Fig 4.1: Criteria pollutants emission distribution for 2010

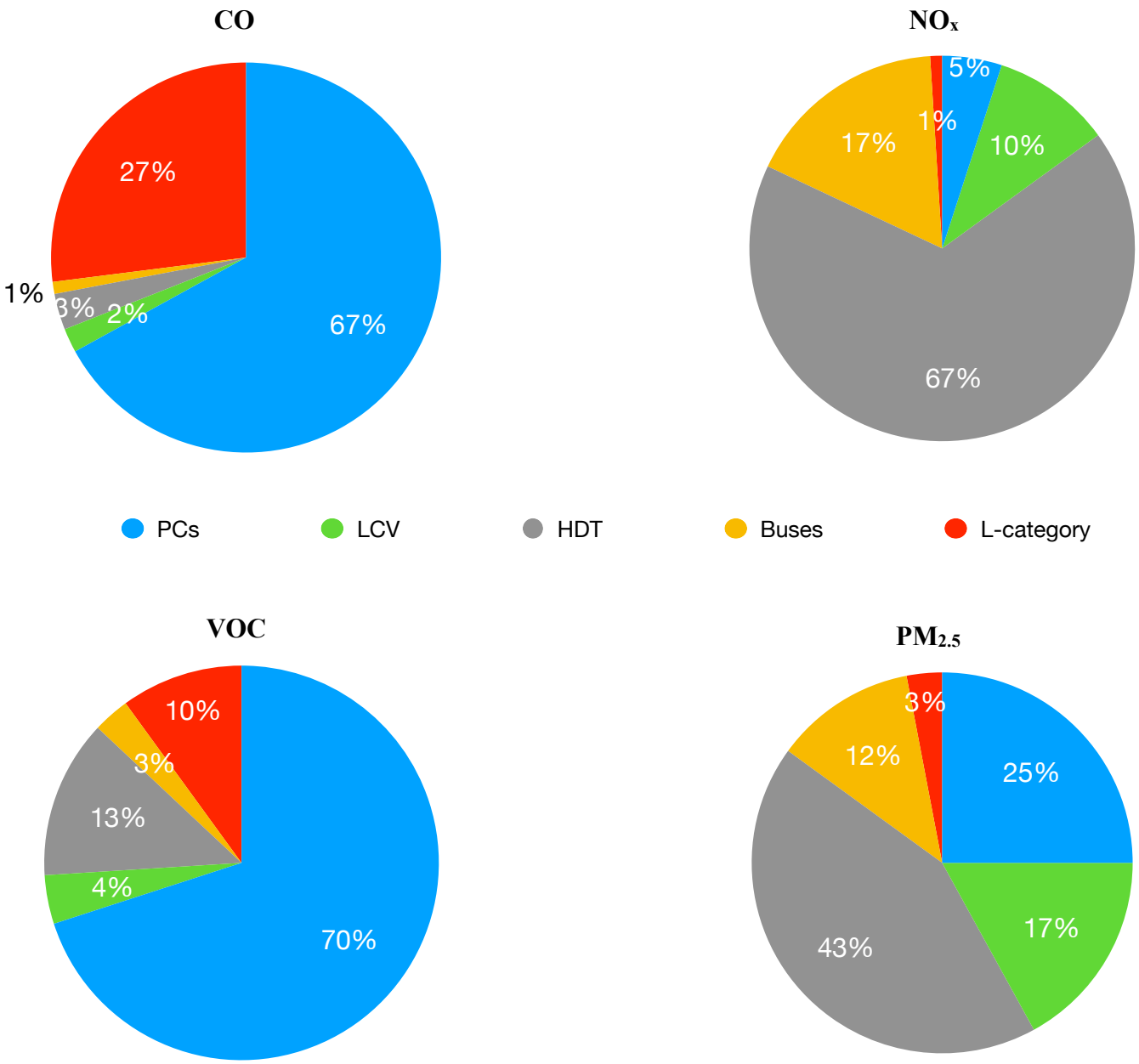

Fig 4.2: Criteria pollutants emission distribution for 2013

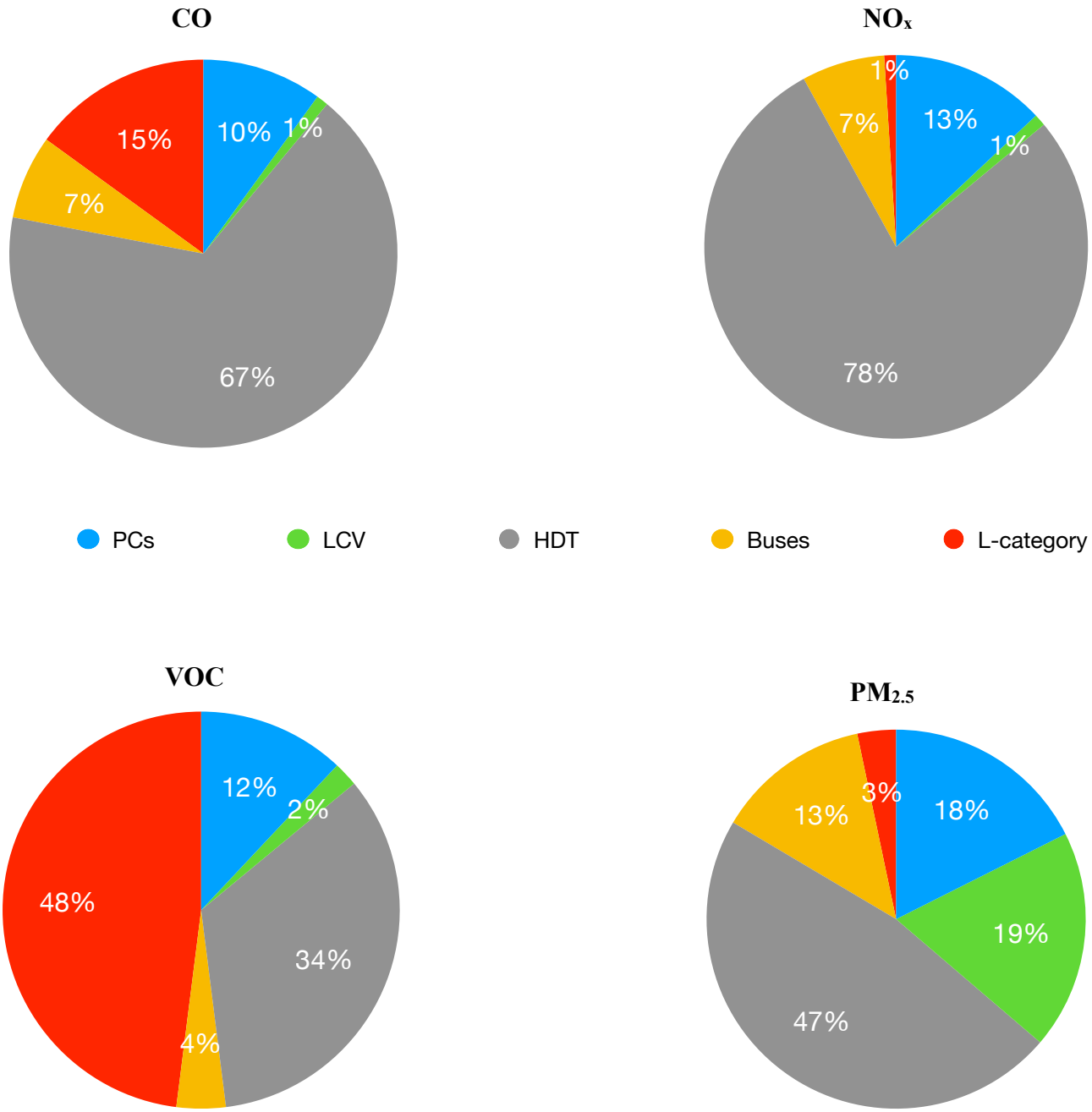

Fig 4.3: Criteria pollutants emission distribution for 2020

4.3 INFERENCES

Referring the vehicular emission inventory for Shimla city in the year 2010, the pollutants released are under limits comparing metropolitan cities like Delhi where their daily emissions are almost equal to a yearly rate of emissions in Shimla. Some reports show approximate emissions of 509 tons/day of CO, 194 tons/day of NO_x, 15tons/day of PM in Delhi for the year 2008-2009[1] which when compared to the results we got for Shimla city is very less.

Referring CBCP's report the estimated emissions in Kolkata[7] are 59.6 tons/day of CO, 44.3 tons/day of NO_x and 4.6 tons/day of PM. Comparing the emissions from those cities, Shimla city's vehicular emissions are least and hence it is a smart city. However we cannot prove here by saying Shimla city is smart city now or not because only vehicular emissions doesn't constitute the criteria for categorising city as smart or not. What we did is one such criteria which can help learn about the features of smart city.

There was increase in every criteria pollutant emissions from 2010 to 2020 but the VOC decreased in the year 2020 because we have applied EURO IV standards which are way efficient and are found to produce lesser emissions. However, other pollutants increased because there was huge increase in number of vehicles. For example, due to drastic increase in number of heavy duty trucks in the year 2013 and 2020 from the year 2010, the NO_x emission increased hugely. The next reason to this increase is heavy duty trucks being diesel fuelled engine and diesels are major emitter of NO_x.

COPERT5 is a European based software and the standards given are all according to EU standards. Therefore, when we have to use for countries like India, the major portion of study is standardising the input data and hence is the major drawback because some accuracy is lost when we standardise Indian standards to the EU standards. Some inaccuracy in the results are certain when we interchange the standards.

CHAPTER 5

CONCLUSIONS

In this paper we have developed the vehicular emission inventory for Shimla city which is considered as smart city, using the European based emission modelling so called COPERT5. The emissions of CO, NO_x, VOC and PM are 372.9 tons, 358 tons, 108.3 tons and 30 tons respectively for the year 2010. The emissions of CO, NO_x, VOC and PM are found t be 881.8 tons, 964.3 tons, 197.9 tons and 34.2 tons respectively for the year 2013. The emissions of CO, NO_x, VOC and PM are estimated as 760.4 tons, 2004.1 tons, 49.2 tons and 56.2 tons respectively for the year 2020.

Petrol is found to be the main source of CO and NO_x. We have compared our studies with emission inventory of other metropolitan cities like Delhi, Kolkata etc. and we found very least rate of emissions in Shimla which is prominent feature of smart city. To curtail the emissions which is increasing every year, we can adopt alternatives like electric cars or may be CNG fuelled vehicles. If alternatives doesn't seem viable, we can work on reducing the old vehicles and get the newer standardised vehicles like BS V and BS VI vehicles which comes with more efficient engines and produces lesser emissions.

Since we used European based software, the standardisation is the major work and is found to be the source of inaccuracy because Indian standards aren't the same as EU standards. Therefore, the best way out is to carefully standardise Indian standards to the ones used in COPERT5 model or use Indian based emission modelling software. However, COPERT5 is based on lesser inputs and detailed results. So we don't have to collect lots of input data because it's already inbuilt in the software. We only have to apply those necessary for our run and thus we can focus on categorising stock configuration and related inputs.

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