EVALUATION OF INSPECTION AND MAINTENANCE PROGRAM ON VEHICLES IN KATHMANDU VALLEY

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1. INTRODUCTION

Since motor vehicles are most popular means of transportation in Kathmandu Valley the number of vehicles are growing on the roads day by day. At the same time these vehicles are contributing quite a large amount of air pollution in the city. Every year a large number of vehicles are imported in Nepal. Most of them are plying in the streets of Kathmandu Valley. One can see many kinds of motor vehicles in the streets of Kathmandu ranging from very old model (seventies) to recently manufactured ones. All these vehicles emit harmful emissions. Consequently, city dwellers have experienced serious air pollution problems. This has lead to regulatory control aimed at controlling vehicle- generated problems.

In order to minimize and control the air pollution from vehicles in Kathmandu Valley HMG/N has initiated following mitigation programs:

- Fixed emission standards for in-use vehicles.
- Introduction of vehicular color rating system with respect to the emission standard in 1995.
- Formulation of NEPAL VEHICLE MASS EMISSION STANDARD, 2056 for different kinds of vehicles and prohibition of imports of vehicles which do not comply with the NVMES, 2056 (1999).
- Banning of the operation of diesel operated three-wheelers in Kathmandu Valley, Pokhara sub-metropolitan and Lumbini area.
- In addition, HMG brought to notification on Nepal Gazette Kartik 25, 2057 about the phasing out vehicles that are older than 20 years and those having 2-stroke engines.
- The Vehicle Anti-Pollution Program (VAPP) training center (under the fifth component of Environment Sector Program Support/Ministry of Population and Environment) has been established with the objective to offer training for specialists and interest groups dealing with the air pollution from motor vehicles in 2001.

With the introduction of emission standards for in-use vehicles Kathmanud Valley Traffic Police (KVTP) has been constantly monitoring the emission level of these vehicles. KVTP conducts vehicular emission tests of vehicles plying in the streets of Kathmandu Valley on regular basis and provides *green sticker* to those vehicles, which pass the test.

KVTP has recorded these test results in a register book manually. These data needs to be further analyzed for suggesting future policy about the reduction of vehicular emissions in the valley. It is not convenient to analyze such a large number of data without using computer. So, it is necessary to enter these data in the computer from these hand-written register books. Once the database is ready and available for analysis many conclusions, suggestions can be made to reduce the vehicular emissions in the valley.

1.1 Objectives

- To evaluate Inspection and Maintenance Program on vehicles in Kathmandu Valley based on emission data obtained from Kathmandu Valley Traffic Police for 2057, 2058, 2059.
- To recommend the effective Inspection and Maintenance Program on vehicles to reduce the vehicular emission.

1.2 Emission standard for in-use vehicles

The existing vehicle emission standard for in-use vehicles for Green Sticker is as follows.

Table 1.1 Idle test emission standard of vehicles (Effective from October 23, 2000)

Vehicle type	Model year	CO, %	HC, ppm	HSU[1], %
Petrol/LPG vehicles	Up to 1980 After 1981	4.5 3.0	1000	-
Three-wheelers	Up to 1991 After 1992	4.5 3.0	7800	-
Diesel vehicles	Up to 1994 After 1995	-	-	75 (k^2 = 3.22 m^{-1}) 65 (k = 2.44 m^{-1})

Source: www.mope.gov.np/environment/green.php

1.3 Structure of this report

This report on Evaluation of Kathmandu Valley Inspection and Maintenance Program on Vehicles is based on emission test data provided by KVTP in the fiscal year 2057-58 and

[1] HSU (Hatridge Smoke Unit) is the percentage opacity measurement for a column of smoke 430mm in length.
[2] **k** is the **coefficient of light absorption**, a measure of ‘blackness’ of the smoke which is independent of the measurement length.

2058-59. The report comprises of six chapters, of which this Introduction is the first. Chapter 2 describes data entry of hand-written emission data from register books into CD-ROM. Chapter 3 describes the emission testing procedures for in-use vehicles. Chapter 4 presents the results of the data analysis, in the form of statistical distributions of emission levels in-use vehicles. Chapter 5 describes the conclusions and chapter 6 recommendations. Chapter 7 includes Appendices.

1.4 Acknowledgements

The authors are very grateful to Dr. Asif Faiz, Operational Advisor, The World Bank, Kathmandu Office for his valuable guidance and suggestions to complete this report.

We are also very grateful for the enthusiastic help and assistance provided by Mr. Krishna Thapa from The World Bank, Kathmandu Office throughout the period of work.

We express our sincere thanks to Mr. Sudhir Shrestha (Mechanical engineer) for his kind cooperation time to time to complete this report.

We would also like to thank Kathmandu Valley Traffic Police for providing emission data for analysis.

2. COMPUTERIZED DATA BASE

Hand-written emission data of petrol-fueled and diesel-fueled vehicles in 2057-58 and 2058-59 have been transferred from the register books to computerized database for analysis purposes. The data is stored in the CD- ROM.

3. EMISSION TESTING PROCEDURES

3.1 Testing Procedure for petrol vehicles

The ETT 8.55 EU Exhaust-gas analyzer is used for measuring the concentration of light vehicles exhaust emissions, the speed and oil temperature of an engine. The measured gas components are CO, HC, CO_2 and O_2. The lambda air ratio is calculated on the basis of the measured emission values. The following measurement ranges are covered:

CO	Carbon Monoxide	0…10.00% vol
HC	Hydrocarbons (using hexane as basis)	0…9999 ppm
CO_2	Carbon Dioxide	0… 18% vol
O_2	Oxygen	0… 21% vol
N	Engine speed	0… 9990 rev/min
T	Oil temperature	0… 150°C
λ	Lambda air ratio	0.50… 2.00

Technical Data

Power supply:	100 V, 120 V, 230 V, 240 V (Selectable with bridges) 50-60 Hz
Permissible ambient temperature:	2°C to 45°C
Permissible relative humidity:	5% to 9%
Air pressure:	700hPa to 1100hPa
Height of installation:	minimum 250 mm from ground
Length of outlet hoses:	minimum 300 mm
Warming up time:	3 minutes
System equalization:	30s
Measurement gas flow:	4l/min
Display delay:	< 15s for 95% measurement accuracy
Weight:	10 kg

Requirements for exhaust analysis

- The engine must be warm (oil temperature > 60°C).
- No aids to starting (automatic or manual) must be operating.
- The exhaust pipe must not leak.
- The engine must have the ignition settings specified by the manufacturer (dwell angle, ignition timing and idling speed).

Test Procedure

1. Once the machine is switched on, it will take 3 minutes for warming up. No measurement is possible during this warming up period.
2. The selection of the petrol vehicles or the LPG gas vehicles is done in the device.
3. The probe is inserted inside the exhaust pipe of the vehicle.
4. After some time, the corresponding values of CO, HC, CO_2, O_2, λ etc. are displayed on the screen and can be printed.
5. Only the value of CO and HC are recorded on the ledger (registration book of KVTP).
6. As per the value obtained from the measurement, the vehicle passes the emission test if it meets the existing standard and gets green sticker; otherwise it fails and has to come for retest after repair.
7. Fee for emission test is Rs. 35.

3.2 Testing Procedure for diesel vehicles

The opacimeter RTM 430 is used for measuring the emissions (of smoke) from diesel vehicles. It can only be used in conjunction with an Emissions System Analyser or emissions analysis measuring instrument. The RTM 430 is used for measuring the absorption coefficient k (m^{-1}) of the exhaust gas emissions of diesel vehicles. The opacity level and the absorption coefficient are a measure of the amount of light absorbed by the soot, white smoke and blue smoke emitted by the engine.

Technical Data

VSM (Supply control module)

Power Supply:	230 V
Operating temperature:	5°C to 45°C
Dimensions (in mm):	430×385×240

Weight:	15 kg

Han-held control unit

Display:	LCD display, 2 lines of 16 characters
Input:	membrane keypad, 9×5 keys, complete alphabet, numbers 0-9, control characters
Operating temperature:	-10°C to 45°C
Heat resistance:	up to 50°C
Dimensions (in mm):	100×200×35
Weight:	500 g

Requirements for exhaust analysis

The engine must be at normal operating temperature, i.e. oil temperature > 80°C.

The exhaust pipe must be free of leaks.

The engine must be tuned in accordance with the manufacturer's specifications (e.g. engine speed, delivery rate and full-load stop).

Test procedure

1. The probe is inserted into the exhaust pipe.
2. The RTM 430 has the warm up phase of 4 minutes. Measurement is not possible during this time.
3. The instructions as shown in the device are followed accordingly.
4. The emission standard is set on the unit.
5. During the test, when "FULL ACCELERATION" is displayed in the screen of hand-held control unit, the vehicle is given the full acceleration and when "IDLE SPEED" is displayed the vehicle is no more accelerated. Then the unit shows the k_1 value and again the same process is repeated and gives the k_2 value and so on. The process is continued till the final k value is displayed and if the final k value, being average of all k values, is below or equal to the standard, then "EGA (EXHAUST-GAS ANALYSIS TEST) PASSED" is displayed in the unit while if it is above the standard, then "EGA FAILED" is displayed. On that basis, the vehicle gets 'Green Sticker' or has to come for retest after repair.

Photographs of emission tests

Figure 3.1 Insertion of probe into tailpipe of diesel vehicle

Figure 3.2 Measuring smoke opacity from diesel vehicle at Satdobato, Lalitpur

Figure 3.3 Emission test of petrol vehicle at KVTP, Putlalisadak, Kathmandu

Figure 3.4 Measuring emissions from petrol vehicles at DoTM, Ekantakuna, Lalitpur

Figure 3.5 Incorrectly inserted probe into the tailpipe

From the survey done in the various auto-repair workshops and vehicle drivers it has been found that most of the vehicles failed in the emission test do not undergo proper repair works. Usually, they go for emission test by doing some adjustments temporarily in order to get ‘green sticker’ and once the ‘green sticker’ is received they bring back the vehicle to previous condition. For example; an adjustment is done on full throttle screw and idle speed screw in diesel vehicles so that the engine speed is lowered during the emission test. Similarly, the idle screw is adjusted in such a way that fuel-air mixture is made lean in petrol vehicles. In the case of very old vehicles they even take out the air filter during the emission test.

The recent roadside emission tests conducted by KVTP revealed that many vehicles did not meet the existing emission standard for in-use vehicles. This also confirms the negligence of proper maintenance and repair of the vehicles by the vehicle owners.

4. ANALYSIS OF THE EMISSION DATA

For the purpose of getting clear characteristic trends from in-use vehicles all incomplete data were discarded. Though the emission test of commercial vehicles is performed twice a year emission data of one time only taken for analysis purpose in order to determine the number of vehicles of that category. The analysis of emission data is carried out separately for gasoline-fueled three-wheelers (also known as tempo), for gasoline-fueled car, jeep, van and for diesel vehicles.

4.1 Three-wheeler

The sample size of three-wheeler tested for CO and HC emissions were 2941 and 1846 in the fiscal year 2057-58 and 2058-59 respectively. It can be seen from the Figures 4.1.1 and 4.1.2 that the maximum number of tempos undergone emission test belongs to model year 1991. The number on the apex shows the failure rate for the model year group.

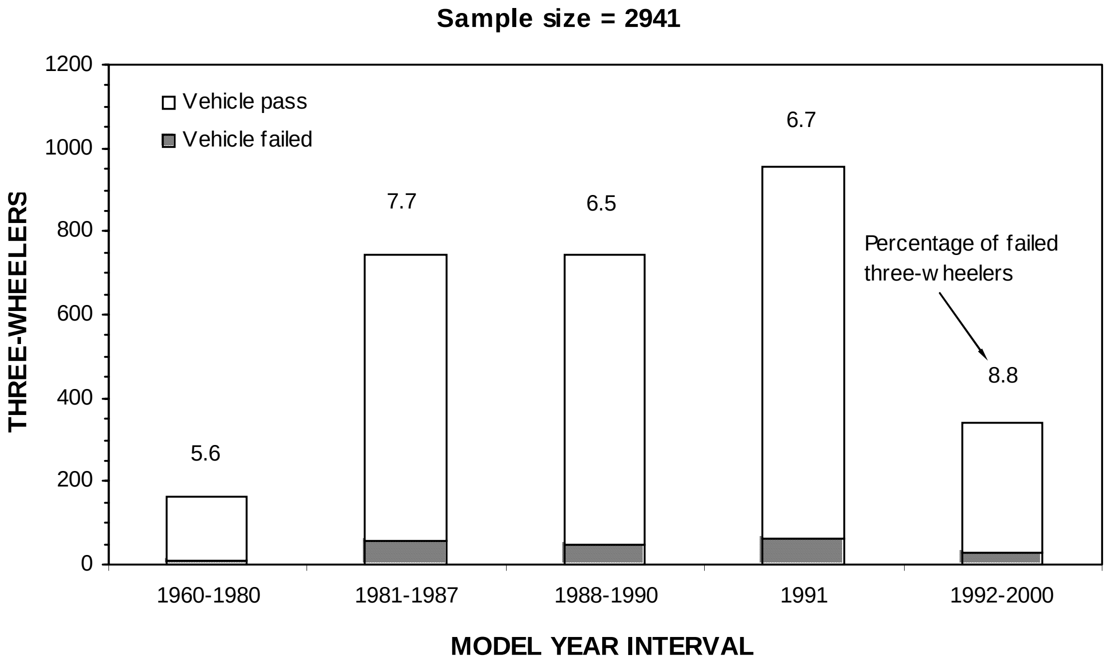

Figure 4.1.1 Percentage of three-wheelers failed in emission test by model year group in 2057-58.

Similarly the number of three-wheelers failed in emission tests were 208 and 255 for fiscal year 2057-58 and 2058-59 respectively (Figures 4.1.1 & 4.1.2). The sample size of three-wheelers tested for emission as well as failed in emission test in 2058-59 is lower than the previous year 2057-58. Higher percentage of failure rate was observed in the group of model years 1992-2000 in both fiscal years.

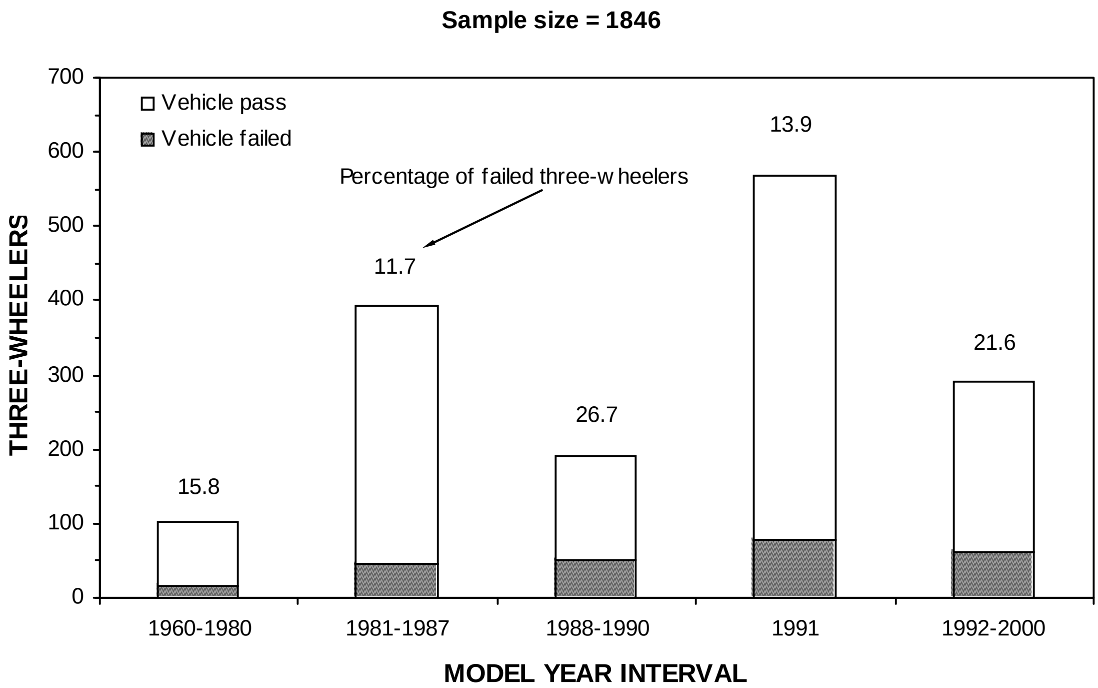

Figure 4.1.2 Percentage of three-wheelers failed in emission test by model year group in 2058-59.

Average CO

The average value of CO emitted from the three-wheelers is highest for the model year 1978 and equal to 5% and this value is higher than the CO emission standard (4.5%) for three-wheelers up to model year 1991. There are few tempos of make year after 1992 that exceeds the CO emission standard (3%) as can be seen from the Figure 4.1.3.

All the three-wheelers except that of model year 1993 met the CO emission standard in the fiscal year 2057-58. It is noticed that the average CO emission is lower than 3% even for many older model three-wheelers; that is, up to model year 1991. This suggests testing the whole population of three-wheelers in one CO emission standard only. Further, it seems that the conditions of three-wheelers were worsened in the fiscal year 2058-59 due to lack of proper maintenance.

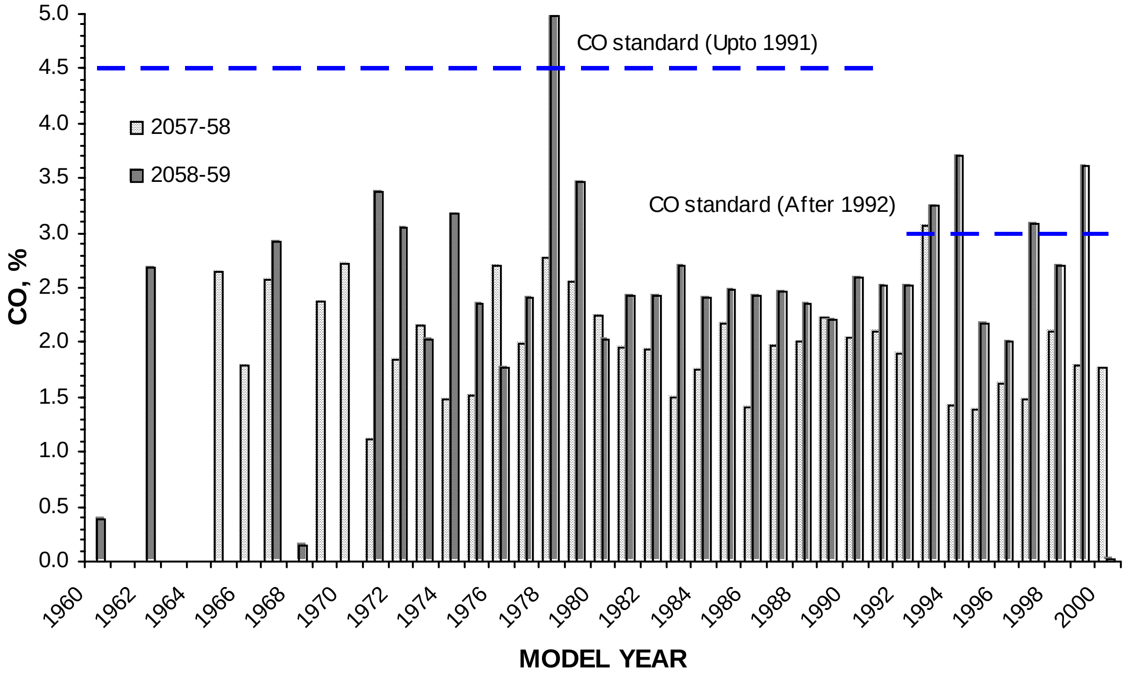

Figure 4.1.3 Average CO emissions from three-wheelers in 2057-58 & 2058-59

Average HC

All the three-wheelers met the HC emission standard (7800 ppm) except that of model year 1978 (Figure 4.1.4). The average values of HC emission of these tempos are below 4000 ppm which is 51.3% lower than the set emission standard for HC.

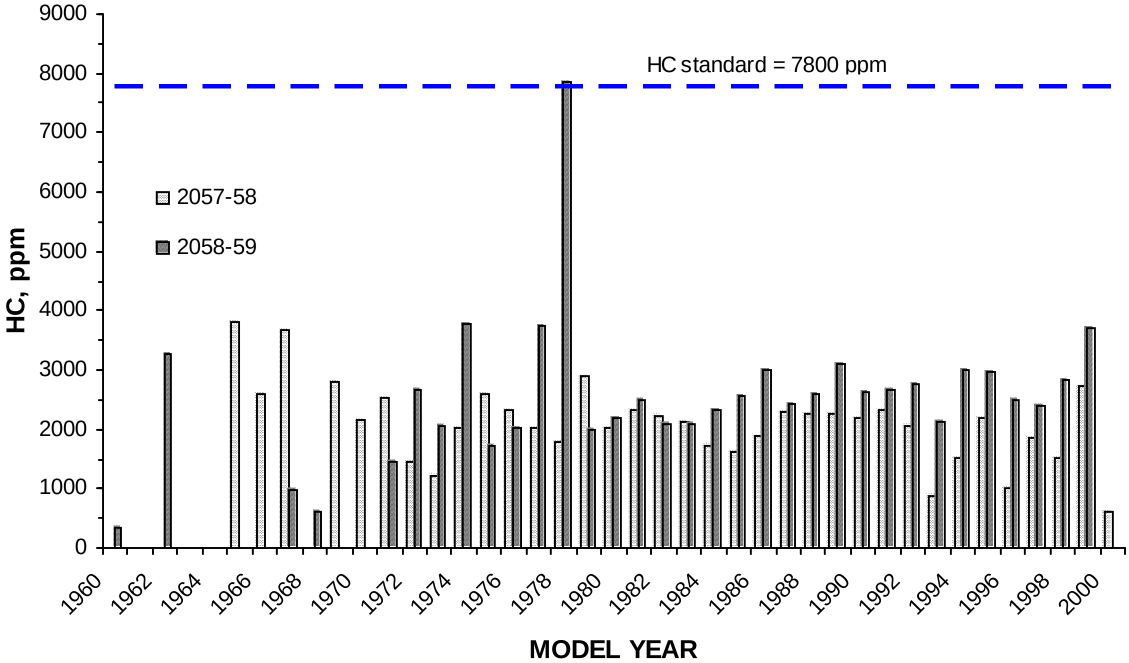

Figure 4.1.4 Average HC emissions from three-wheelers in 2057-58 & 2058-59

The CO emission of the maximum number of three-wheelers falls in the range of 2-2.5% (Figure 4.1.5). There are about 13% of three-wheelers whose CO emission level exceed 4.5% and can be considered as gross polluters.

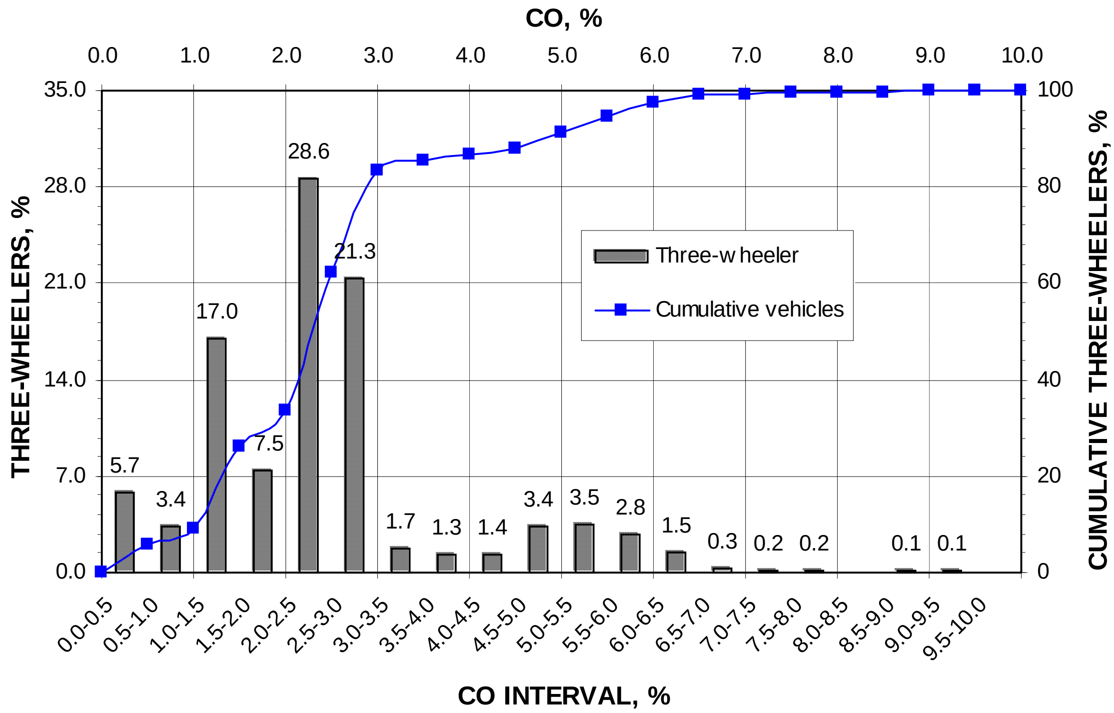

Figure 4.1.5 CO distribution from three-wheelers in 2058-59

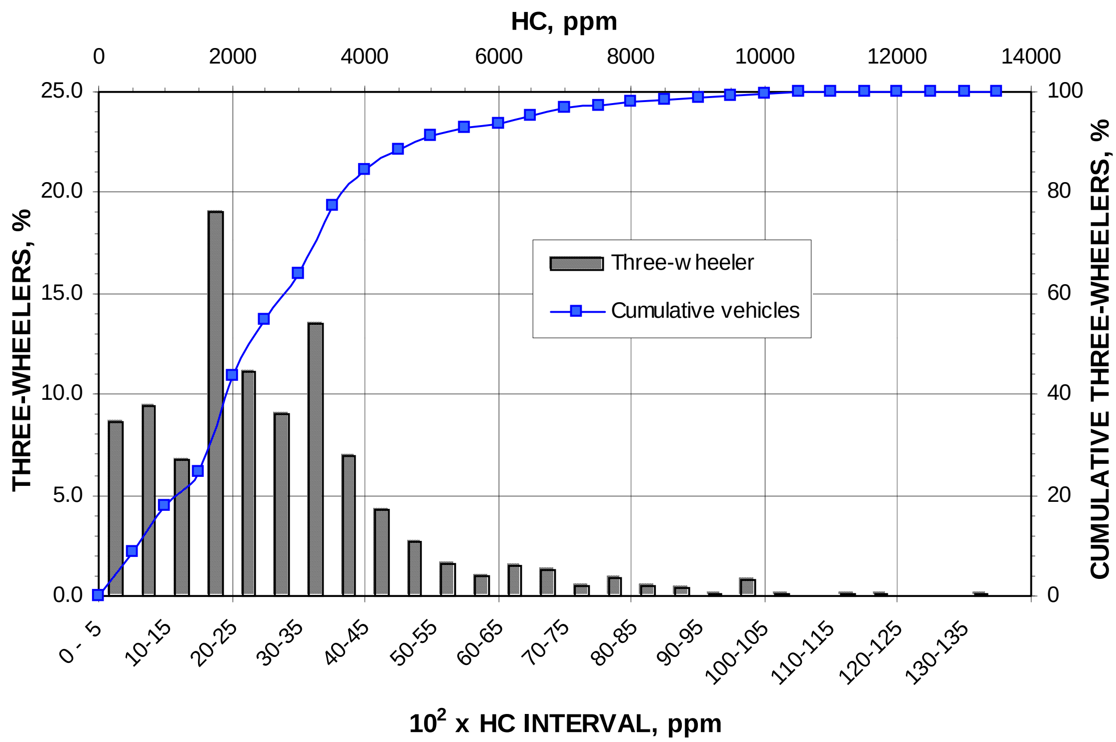

Figure 4.1.6 HC distribution from three-wheelers in 2058-59

Similarly, there are maximum number of three-wheelers emitting HC in the range of 1500-2000 ppm. With the existing HC emission standard there exists a little number of three-wheelers that are exceeding HC emission standard. These results indicate that the existing HC emission can be tightened. Results of CO and HC emissions from three-wheelers in the fiscal year 2058-59 are presented in the Appendix B.

CO and HC distribution

The comparative CO and HC distributions from three-wheelers in the year 2057-58 and 2058-59 are presented in the figures 4.1.7 and 4.1.8 respectively. In both figures it is shown that the cumulative distributions of emissions from three-wheelers are decreased in the year 2058-59 in comparison to previous year 2057-58.

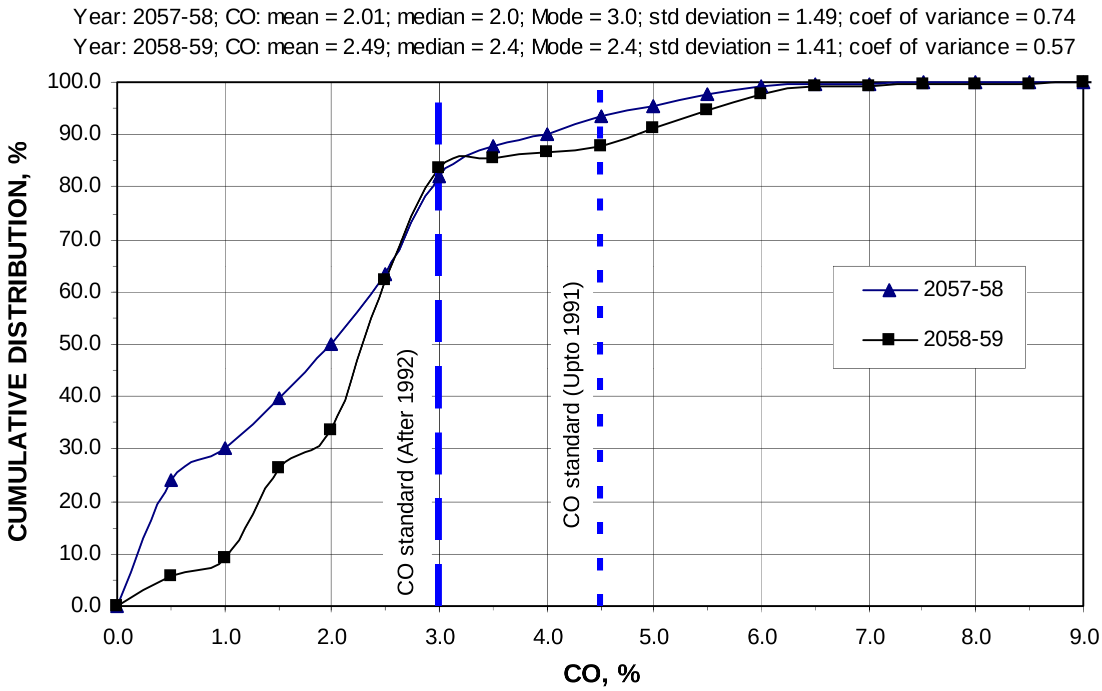

Figure 4.1.7 CO distribution from three-wheelers in 2057-58 & 2058-59

About 83% of the population of three-wheelers is meeting the emission standard of CO (3%) in both years indicating that there is no need of having separate CO emission standard for three-wheelers of model year up to 1991. Similarly about 85% of the tempos have HC emission less than 4000 ppm showing that the existing emission standard is very high and about 98% of entire population of tempos is meeting it (Figure 4.1.8).

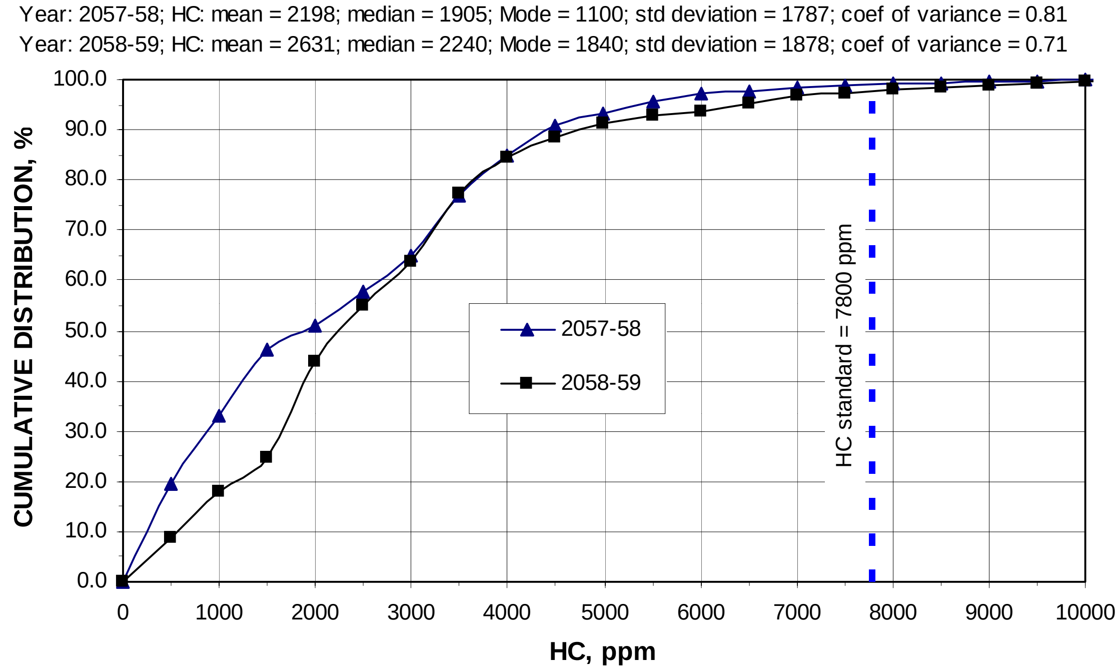

Figure 4.1.8 HC distribution from three-wheelers in 2057-58 & 2058-59

CO and HC distribution by emission standard

There is no significance difference in CO & HC distribution between model year up to 1991 and after 1992 as can be seen from the Figures 4.1.9 and 4.1.10 respectively. About 90% of 342 tempos of model year after 1992 met the emission standard of CO.

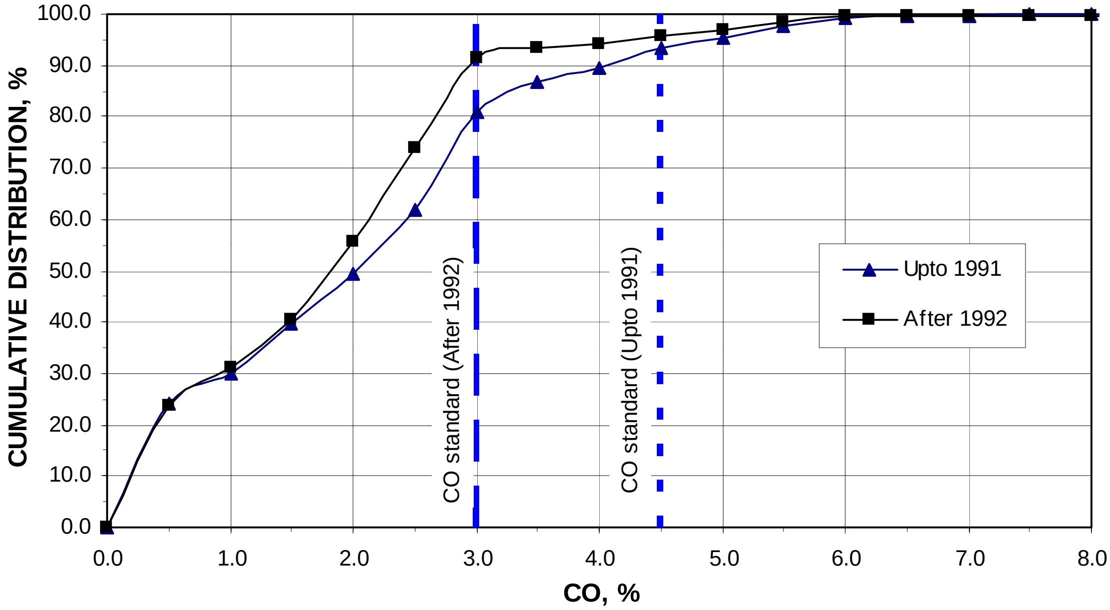

Figure 4.1.9 CO distribution from three-wheelers by model year up to 1991 & after 1992 in 2057-58

Similarly 93% of 2599 tempos of model year up to 1991 met the emission standard of CO (4.5%). About 80% of these three-wheelers are emitting CO below 3%.

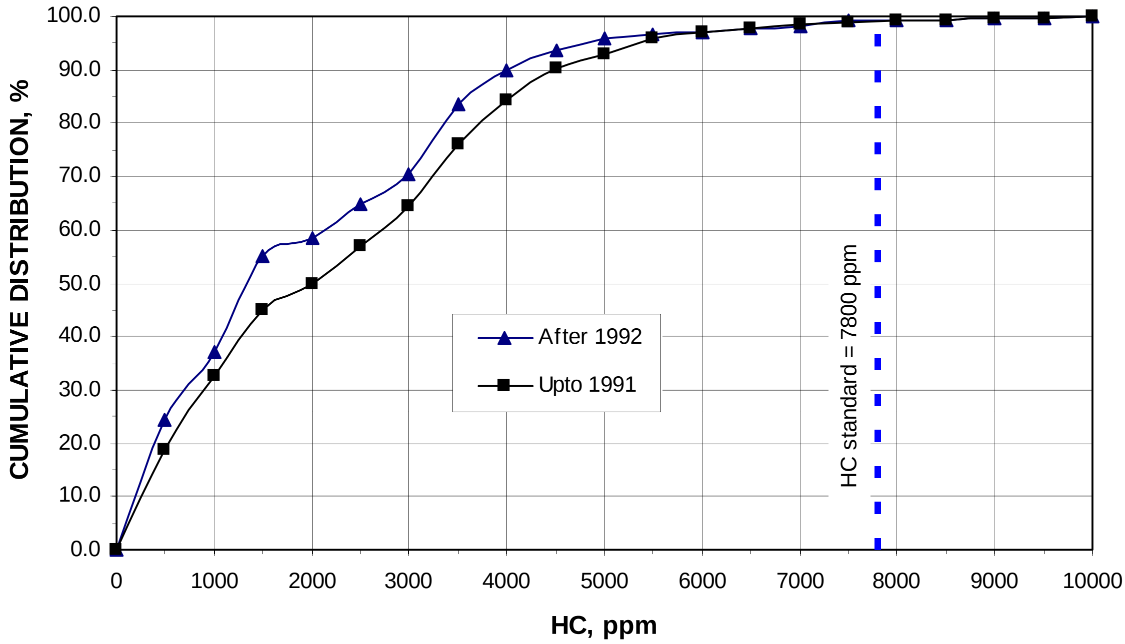

Figure 4.1.10 HC distribution from three-wheelers by model year up to 1991 & after 1992 in 2057-58

Similarly, the HC distribution from three-wheelers undergone emission test in 2057-58 shows that almost 97% of the tempos met the emission standard of HC (Figure 4.1.10). About 85% of these three-wheelers have HC emissions below 4000 ppm.

The cumulative distribution of three-wheelers (model year up to 1991 and after 1992) for CO and HC emissions measured in 2058-59 are presented in Appendix B. Three-wheelers with model year up to 1991 are producing lower emission of CO and HC than that of model year after 1992.

CO and HC distribution by age

HMG/N has once published a notice to ban 20 years old vehicles plying in the streets of Kathmandu Valley but it has not implemented till now. Keeping this in view the CO and HC emissions from three-wheelers of ages 20 years older and below 20 years was compared. The results demonstrate that there is no significant difference between these two groups as can be seen from the following figures.

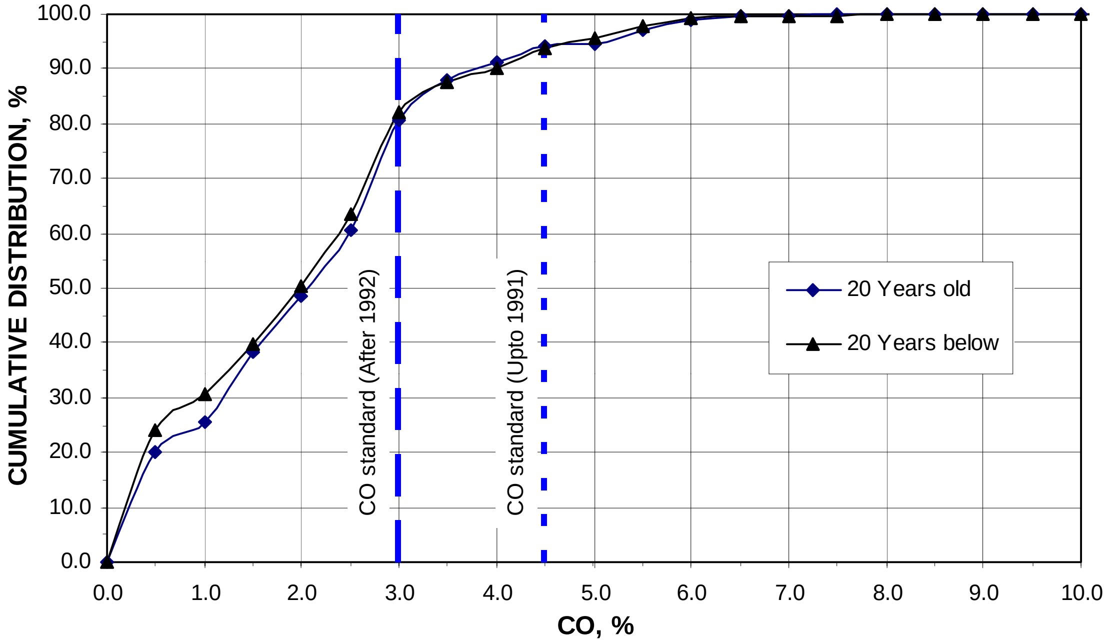

Figure 4.1.11 CO distribution from three-wheelers by age in 2057-58

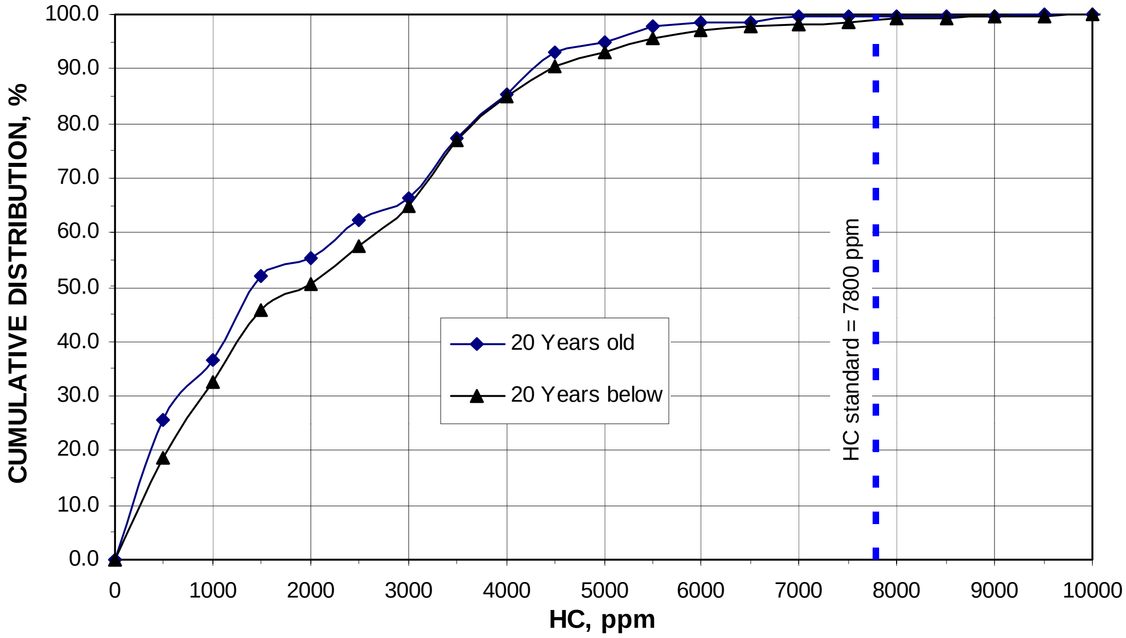

Figure 4.1.12 HC distribution from three-wheelers by age in 2057-58

Similar results were also obtained from the sample taken in the year 2058-59 and are illustrated in the Appendix B.

CO and HC distribution by category

The comparative cumulative distributions of CO and HC emissions from commercial and private three-wheelers reveal that private tempos (though little in number) produce less average CO and HC emissions than the commercial tempos in the year 2057-58 (Figures 4.1.13 & 4.1.14).

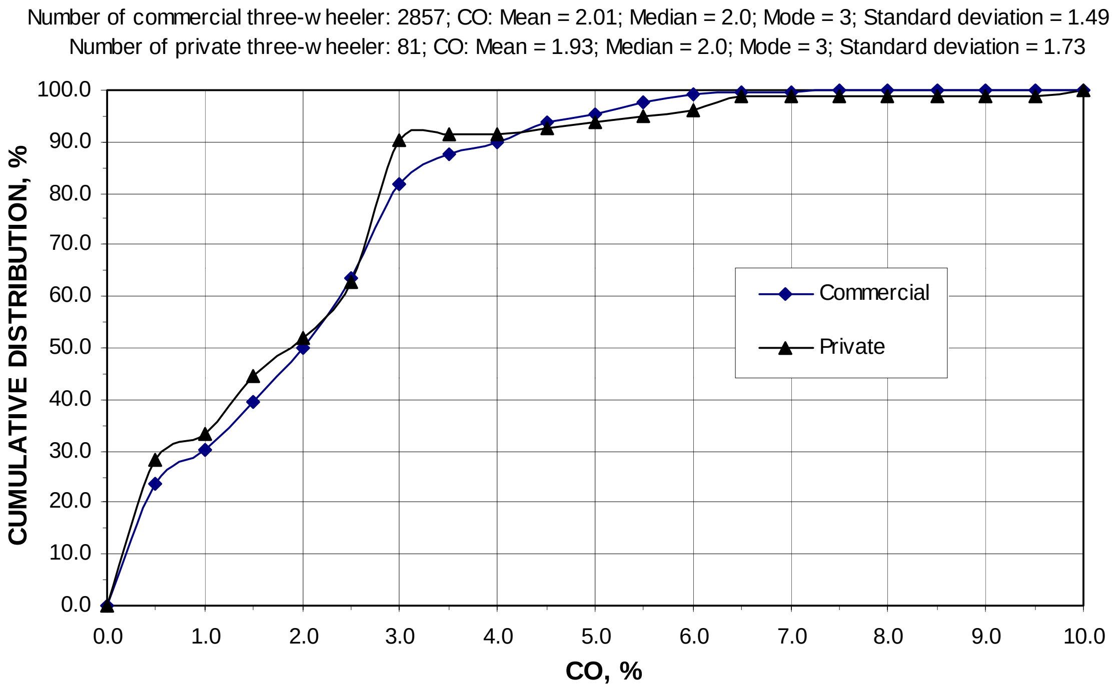

Figure 4.1.13 CO distribution from three-wheelers by category in 2057-58

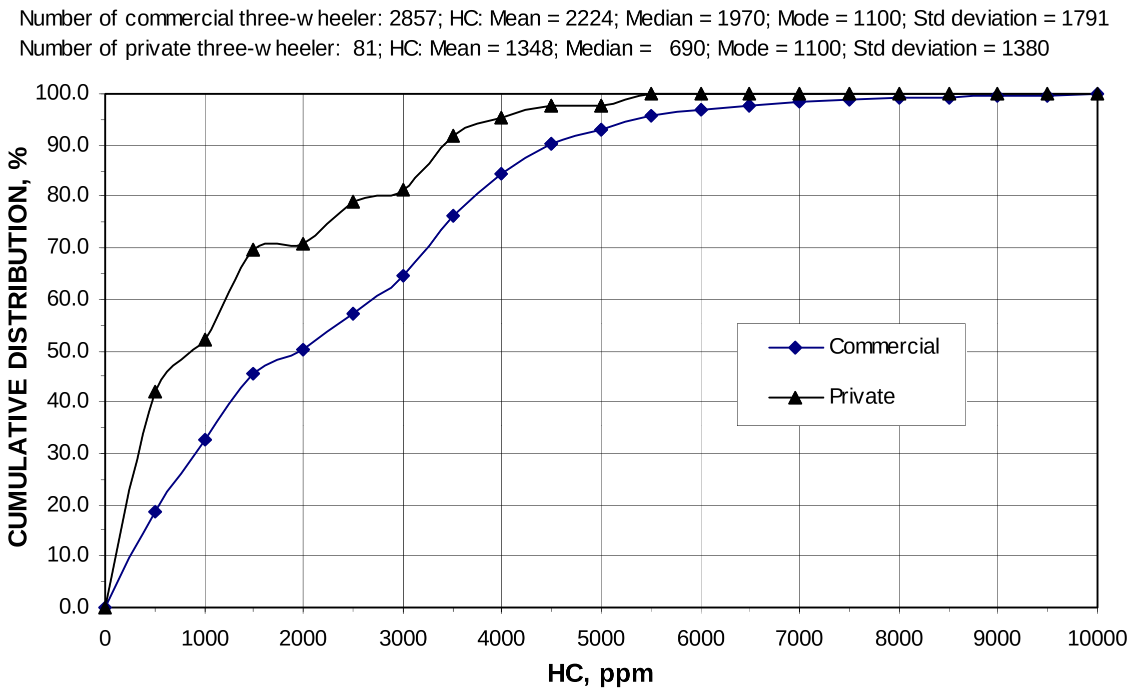

Figure 4.1.14 HC distribution from three-wheeler by category in 2057-58

Similar distributions of CO and HC are found from three-wheelers in 2058-59. Thus it can be concluded from the figures that the private three-wheelers are emitting comparatively less CO and HC (Appendix B).

Private three-wheelers are emitting more HC emissions in 2058-59 than previous year indicating that they are poorly maintained (Figure 4.1.15).

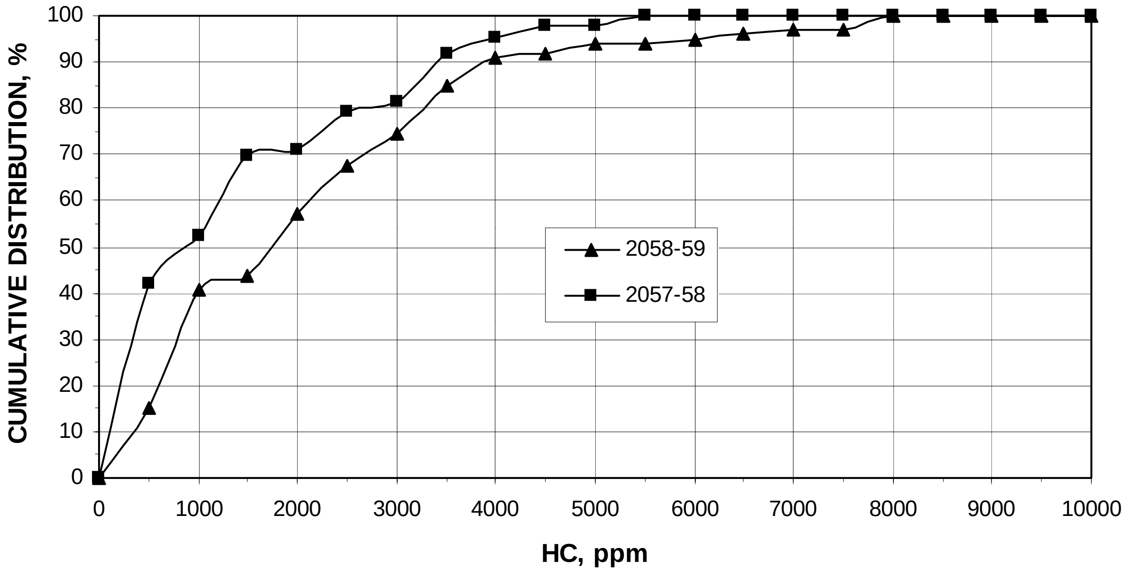

Figure 4.1.15 HC distribution from private three-wheelers in the year 2057-58 and 2058-59

Cumulative distribution of emissions

Cumulative distribution of CO and HC emissions from three-wheelers in 2057-58 and 2058-59 are presented in the figures 4.1.17 - 4.1.20 respectively. 50% of CO emission is contributed by 26% of three-wheelers in the year 2057-58 and by 30% of vehicles in the year 2058-59 respectively.

Similarly, 23% of three-wheelers have emitted 50% of HC emission in the year 2057-58 and 27% of tempos have contributed same percent of HC emission in the year 2058-59 respectively. These emissions indicate that the number of gross polluting three-wheelers is increased from 2057-58 to year 2058-59 even though the sample size decreased from 2941 to 1846 for the same period.

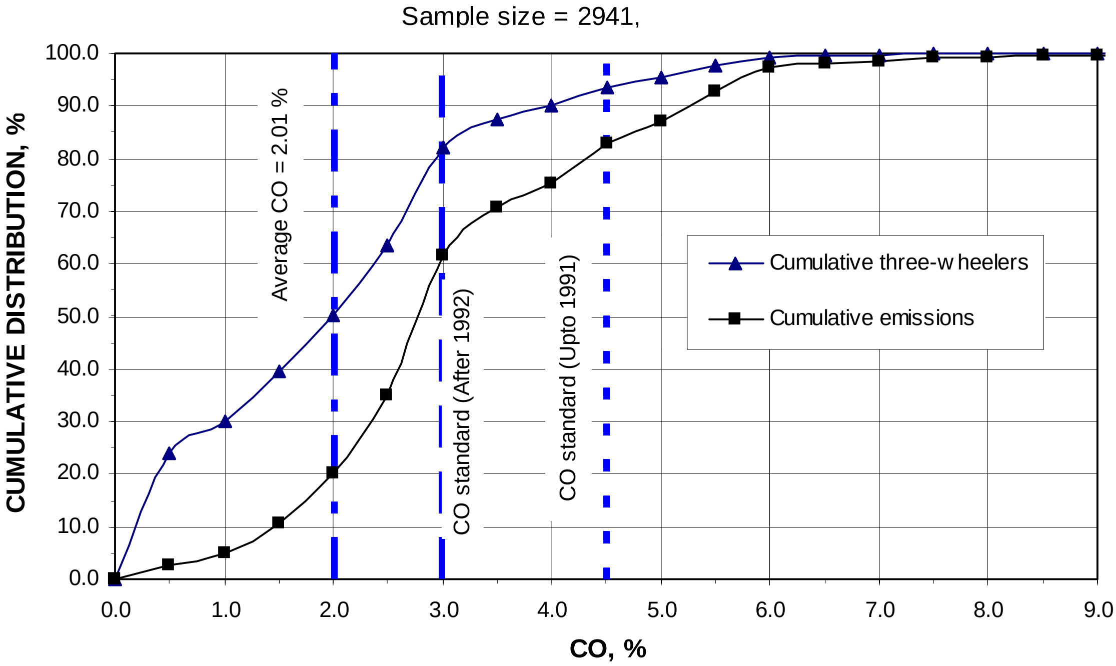

Figure 4.1.16 Cumulative distribution of CO emission from three-wheelers in 2057-58

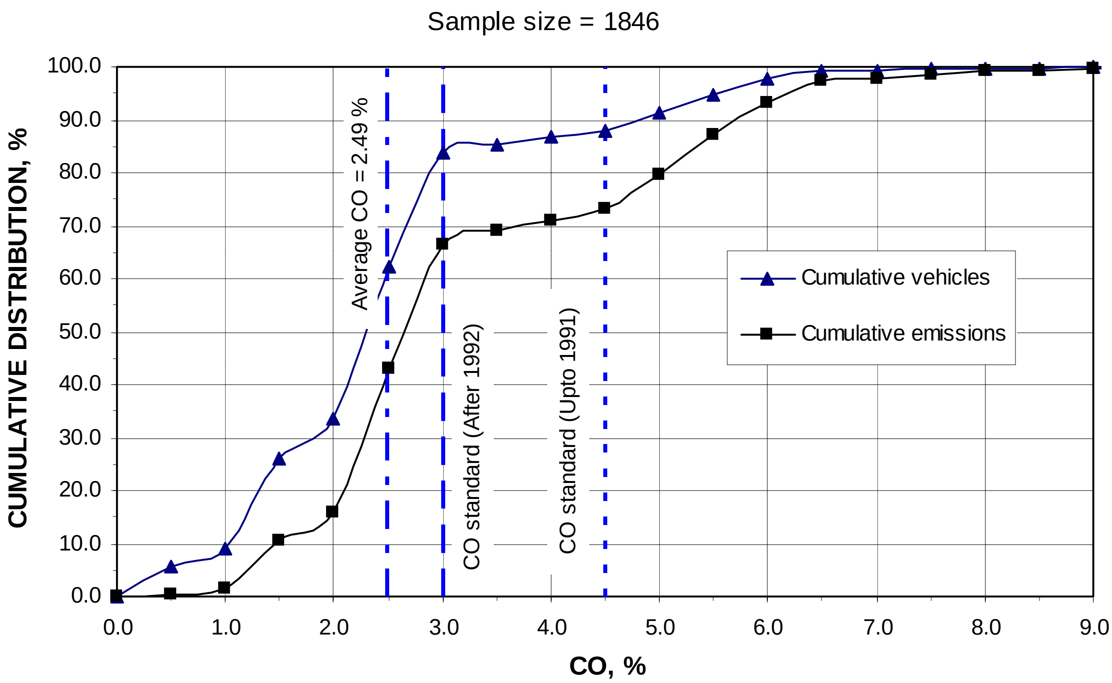

Figure 4.1.17 Cumulative distribution of CO emissions from three-wheelers in 2058-59

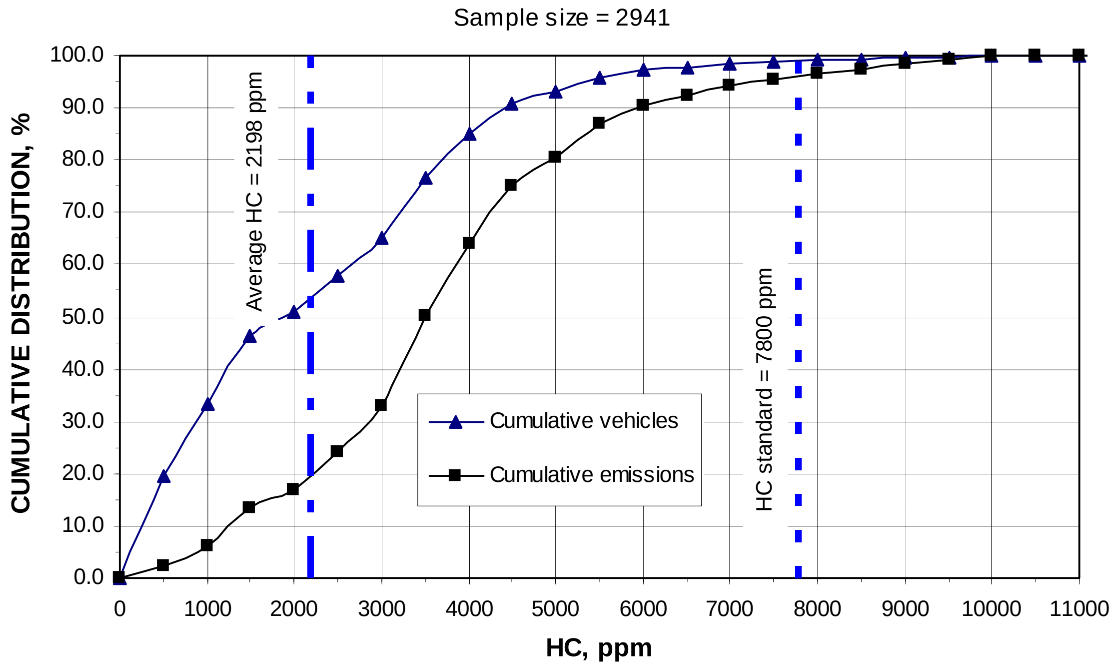

Figure 4.1.18 Cumulative distribution of HC from three-wheelers in 2057-58

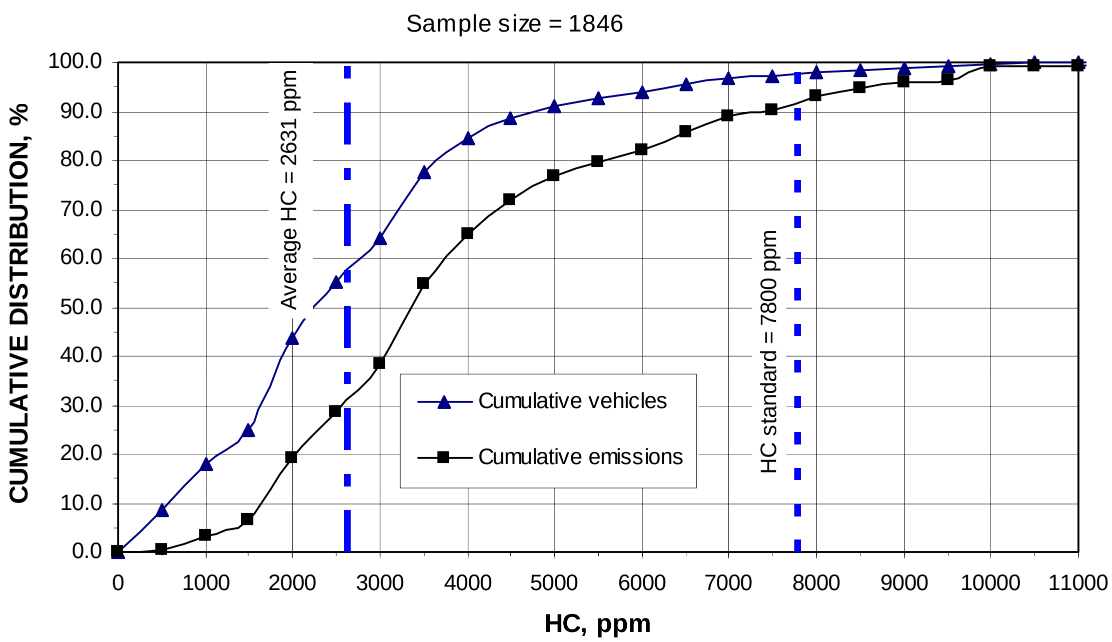

Figure 4.1.19 Cumulative distribution of HC from three-wheelers in 2058-59

Emission test of three-wheelers before and after repair

Once the vehicle fails in the emission test it has to come for test again after repairing the vehicle in order to obtain green sticker. The average values CO and HC before and after repair of three-wheelers are shown in Figures 4.1.20 and 4.1.21 respectively. The results show the significant decrease in average values of CO and HC after repair.

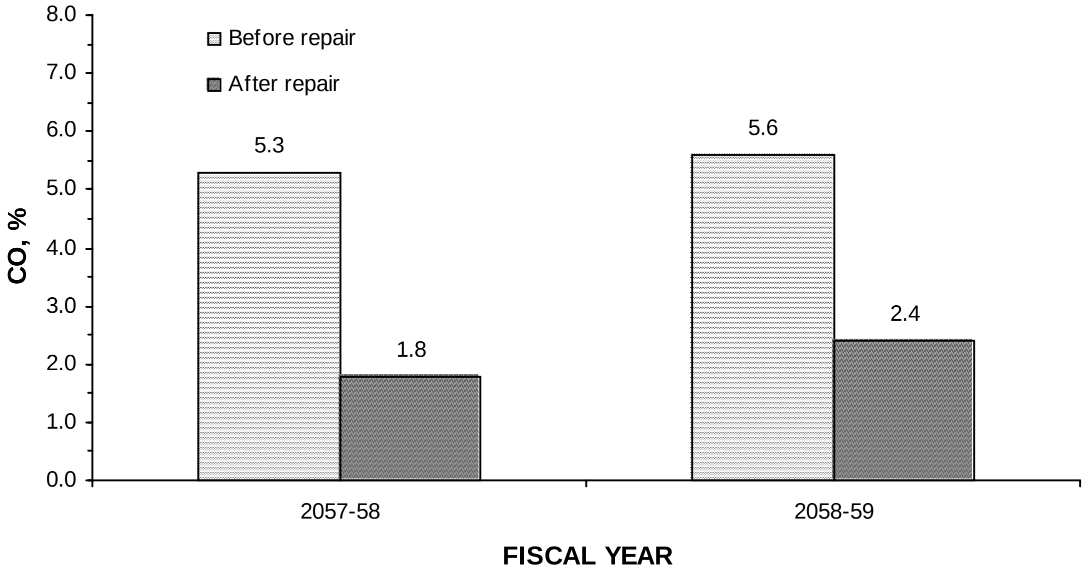

Figure 4.1.20 Average CO from three-wheelers before and after repair in different fiscal year

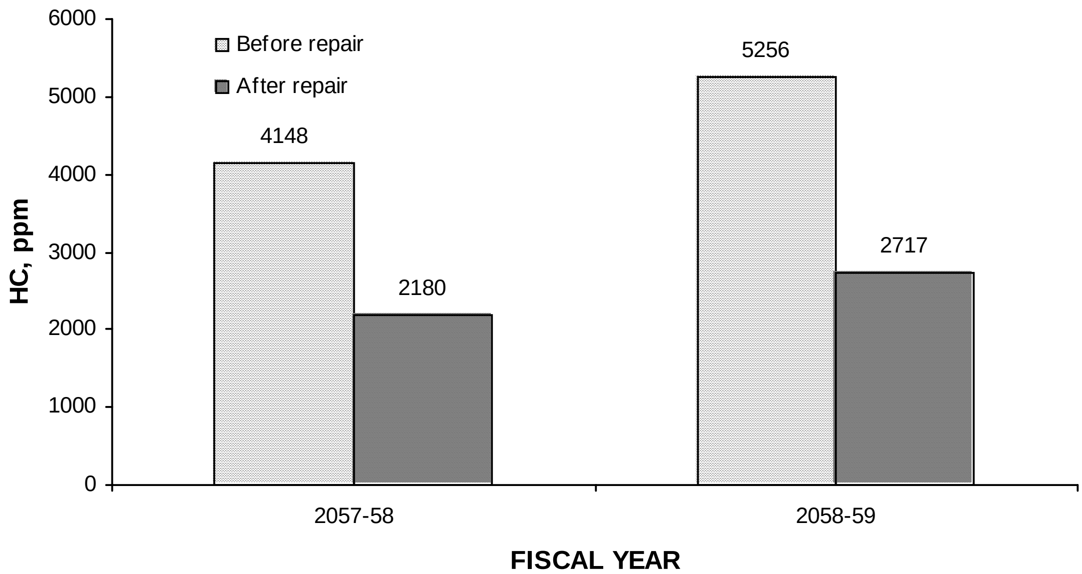

Figure 4.1.21 Average HC from three-wheelers before and after repair in different fiscal year

4.2 Four wheelers petrol vehicles

The four wheeler petrol vehicles include the light duty vehicles like car, van and jeep. They are further categorized by use for example; commercial, governmental, diplomatic, private, corporation and tourism for analysis. The emission test data from the vehicles are taken from 2057/3/8 to 2058/3/7 in fiscal year 2057/58 and from 2058/3/11 to 2058/3/6 in 2058/59. The number of vehicles tested in the years 2057/58 and 2058/59 is 11435 and 11332 respectively and the corresponding numbers by category and types are presented in Table 4.2.1.

Table 4.2.1 Number of petrol vehicles tested in 2057/58 and 2058/59

By category

Year	Total	Commercial	Government	Diplomatic	Private	Corporation	Tourism
2057/58	11435	3896	244	255	6584	175	281
2058/59	11332	3854	314	207	6521	167	269

By type

Year	Total	Car	Van	Jeep
2057/58	11435	9740	645	1050
2058/59	11332	9928	448	956

The vehicles passed and failed in the emission test in two years by model year groups are presented in Figures 4.2.1 and 4.2.2 respectively. The number of vehicles of model year group1996-1998 is higher in both years. The failure rate are similar from the model years group 1960-1980 to model year group 1996-19998; while there is considerable decrease in failure rate in the vehicles of model group 1999-2001 in both fiscal years. However, higher percentage of failure rate is seen in model year group 1960-1980.

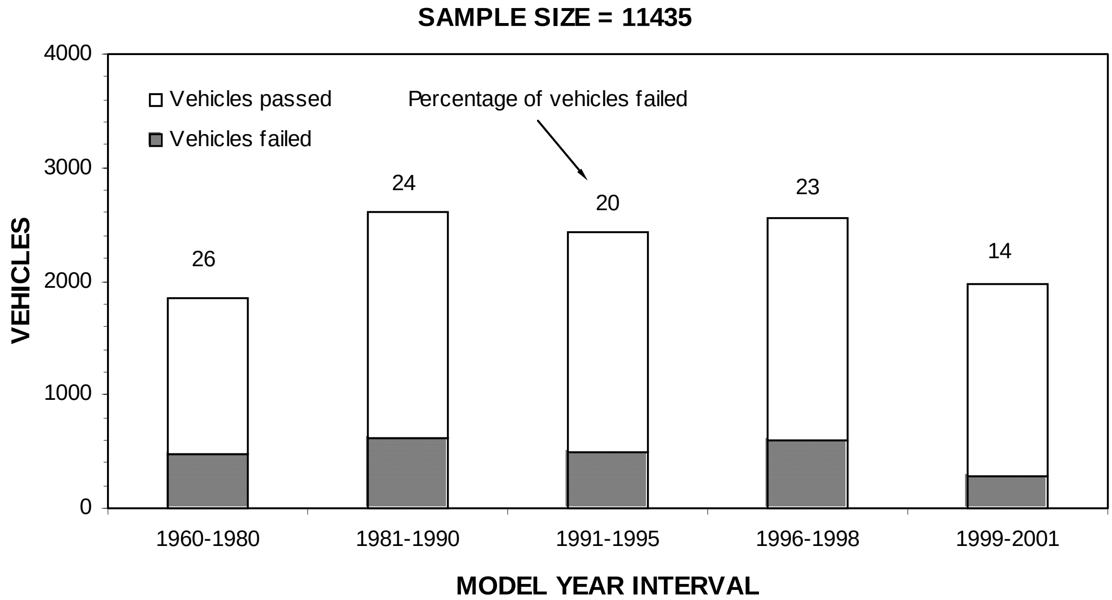

Figure 4.2.1 Percentage of four wheelers failed in emission test by model year in 2057/58

The failure rate has increased in all the model groups in 2058/59 compared to model year group in 2057/58.

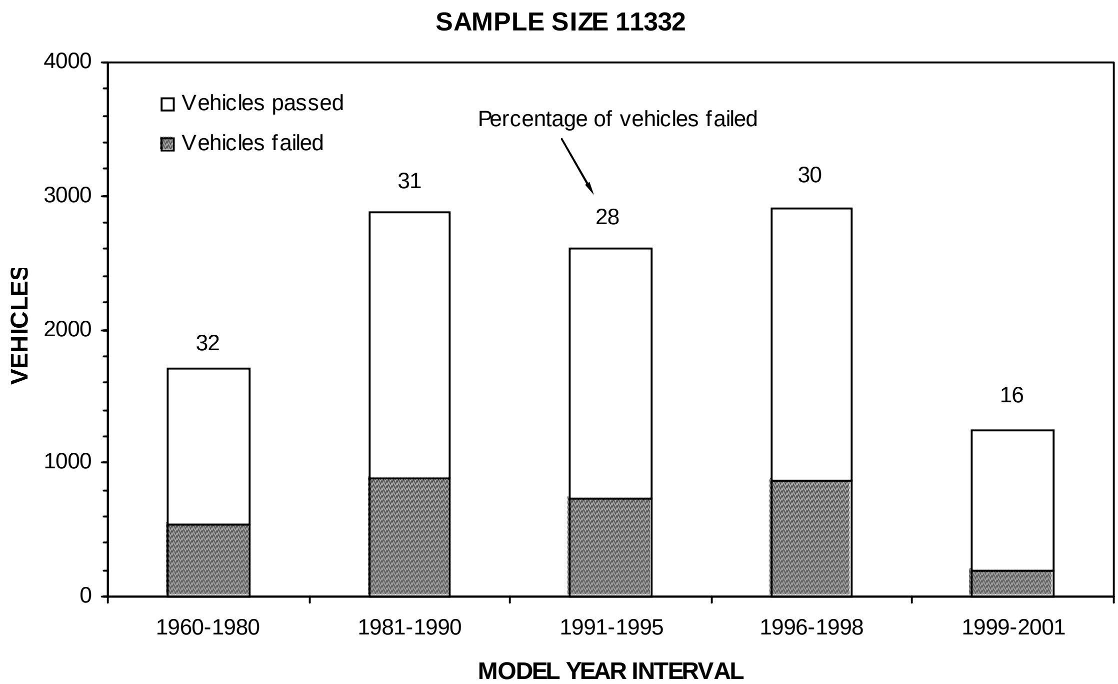

Figure 4.2.2 Percentage of four wheelers failed in emission test by model year in 2058/59

Average CO Emission

The average CO emissions from the vehicles by model years in two years are shown in Figure 4.2.3. The average CO emission from the petrol vehicles in 2057/58 is 1.1% and 1.7% in 2058/59. Though the CO emission standards are different for the vehicles of model year up to 1980 (4.5%) and for the vehicles of model after 1981 (3%), the vehicles of all the models are within the emission standard of 3%. It shows that there is no need of the two emission standards and the existing CO standards can be lowered to only one value of 3% or even less.

There is not significant decrease in average CO emission with the latest (newer) model year of vehicles. Only after the model 1999, the CO emission is decreasing considerably. It shows that there is not good relationship between the model year (vehicles age) and the CO emission. The correlation was checked between the model years and CO emission for two year and the correlation coefficient for the year 2057/58 was –0.56 and that for 2058/59 was –0.28. It shows that in 2057/58, there was moderate degree of negative correlation between model year and CO emission; that is, CO emission has decreased with increase in model year but only to a little extent. However in 2058/59, there is poor negative correlation between the model year and CO emission; that is, the decreasing of CO emission with increase in model years in not quite significant.

Further, the average CO emission is found higher in 2058/59 than the average CO emission in 2057/58. It indicates the worse conditions of the vehicles in terms of emission due to lack of proper maintenance.

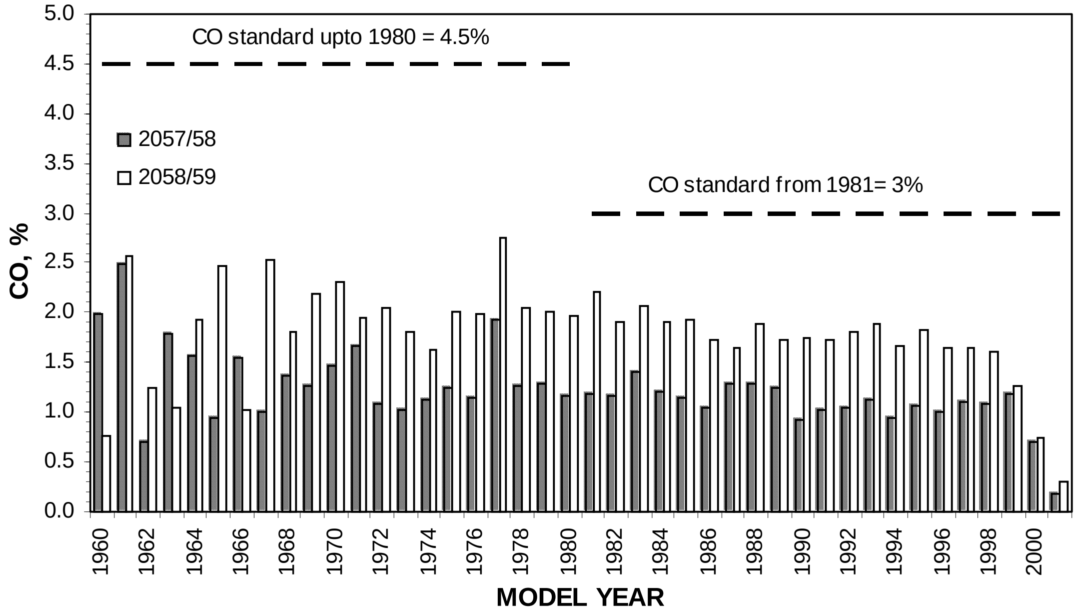

Figure 4.2.3 Average CO emissions from four wheelers in 2057/58 and 2058/59

Average HC Emission

The average HC emission of the four wheelers is shown in figure 4.2.4 by model year of the vehicles. Likewise in CO emission, most of the vehicles of all models are within the emission standard (1000 ppm HC). Only the vehicles of model 1963, 1964, 1969 are out of the emission standard. It is seen from the figure that up to model year 1996, the average HC emission is random while from model year 1996, the HC emission has been decreasing. The correlation coefficient for HC emission was –0.55 in 2057/58 and –0.23 in 2058/59. Though there was some moderate degree of decreasing pattern of HC emission in 2057/58, the relationship between the model year (vehicles age) and HC emission is quite poor in 2058/59. The average HC emission is increased in 2058/59 compared to 2057/58.

The average HC from the four wheelers is 529.27 ppm in 2057/58 and 705.6 in 2058/59 which are quite lower than the existing emission standard. The average values of HC emission from most of the models are below the existing HC standard (Figure 4.2.4).

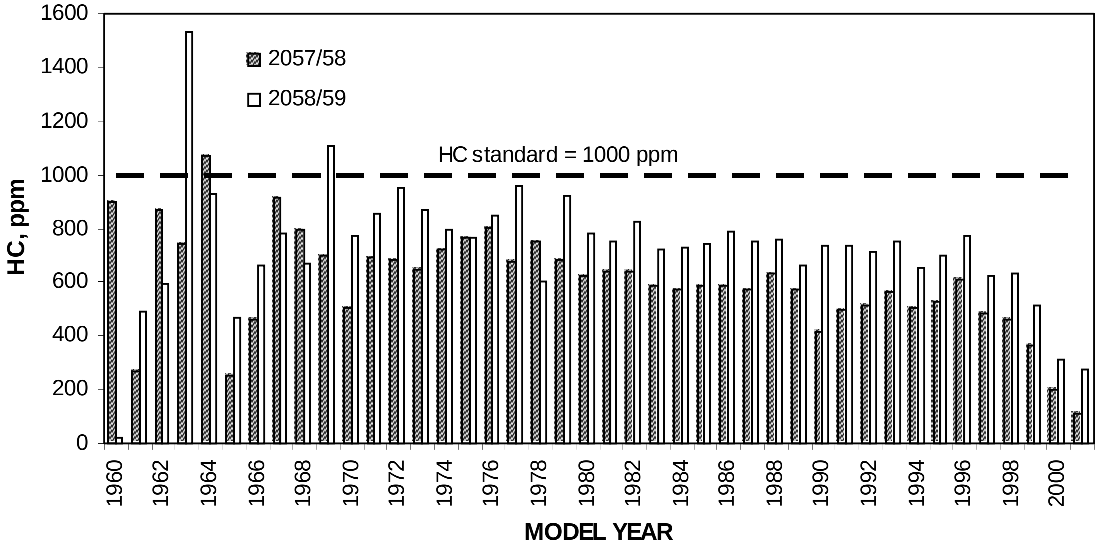

Figure 4.2.4 Average HC emissions from four wheelers in 2057/58 and 2058/59

The CO and HC distribution from the four wheelers in 2057/58 are shown in Figures 4.2.5 and 4.2.6. Higher percentages of vehicles are in the range of 0-0.5% CO and 100-500 ppm HC respectively. Both the CO and HC distribution seem to be positively skewed.

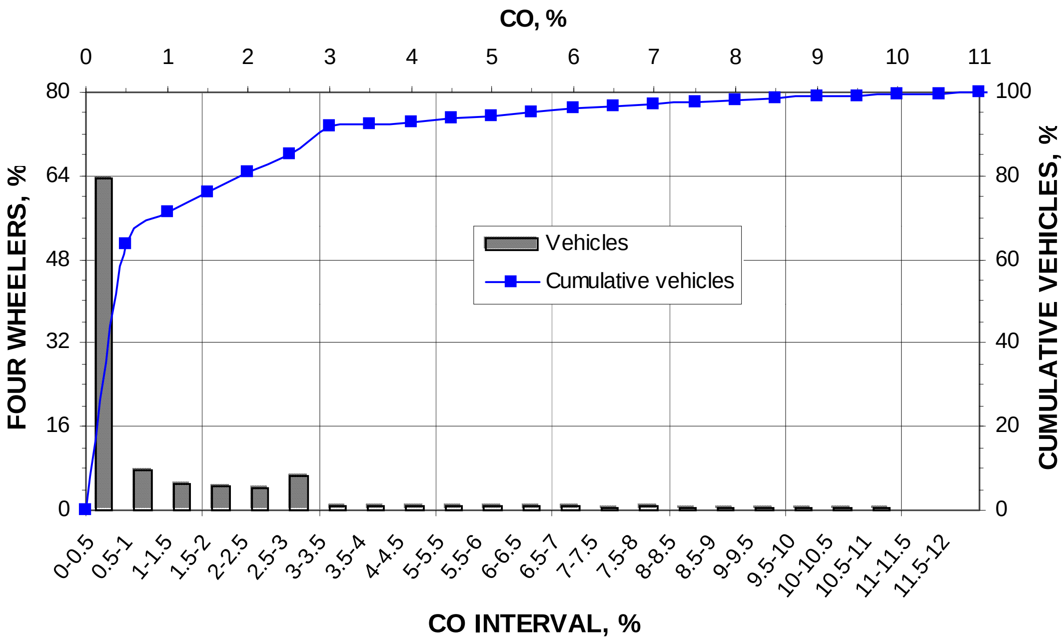

Figure 4.2.5 CO distribution from four wheelers in 2057/58

About 90% of the vehicles are within the emission standard of 3% CO, likewise, 85% of the vehicles are within the emission standard of 1000 ppm HC. So a very little number of vehicles of about 10-15 % are exceeding the emission standard causing the gross pollution. Further, the higher percentage of vehicles is in the range of 0-0.5% CO (Figure 4.2.5) and 100-500 ppm HC (Figure 4.2.6) indicating that the existing emission standard can be tightened.

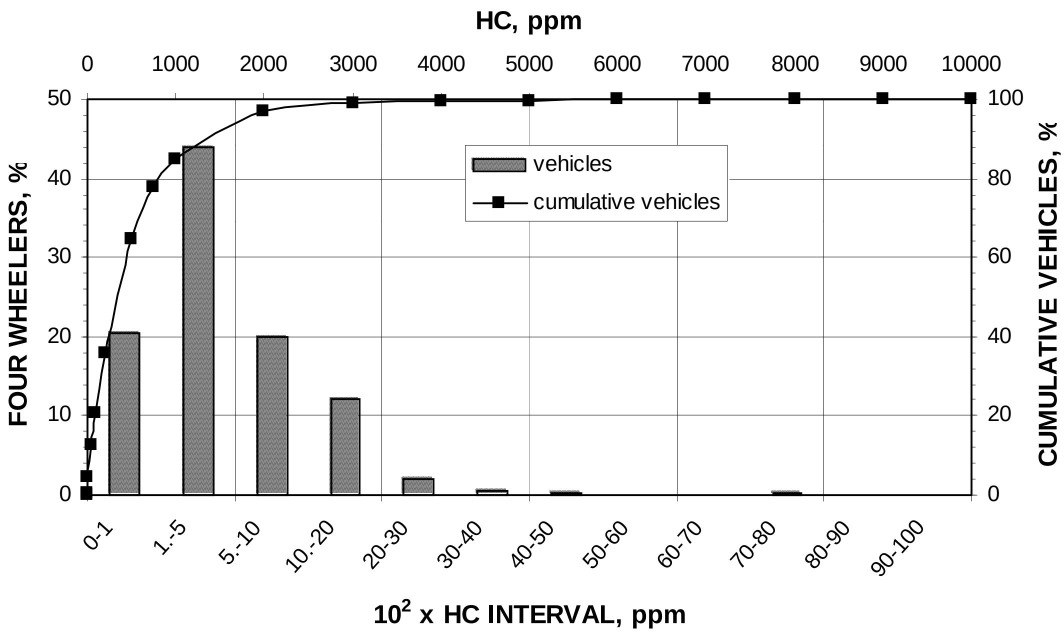

Figure 4.2.6 HC distribution from four wheelers in 2057/58

Cumulative CO and HC distribution

The cumulative CO and HC distribution from four wheelers in two years are shown in Figures 4.2.7 and 4.2.8 respectively. In both the cases, the cumulative distributions of emissions are decreased in 2058/59 compared to that in 2057/58. The percentage of vehicles within the emission standard is decreased in 2058/59. Almost 91 % of the vehicles are within the CO standard of 3% and 96 % of the vehicles are within the HC standard of 1000 ppm in 2057/58, while about 87% of the vehicles are within the CO emission standard and 82% of the vehicles have met the HC emission standard in 2058/59. The cumulative distribution of vehicles in 2057/58 is higher than the distribution of vehicles in 2058/59.

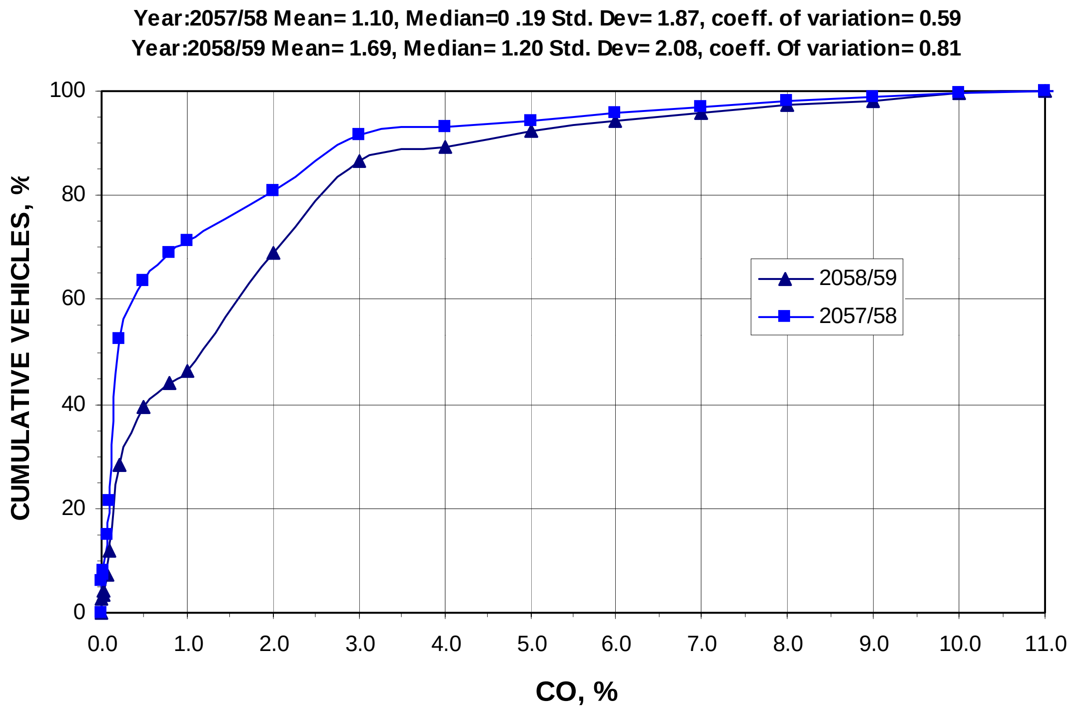

Figure 4.2.7 CO distribution from four wheelers in 2057/58 and 2058/59

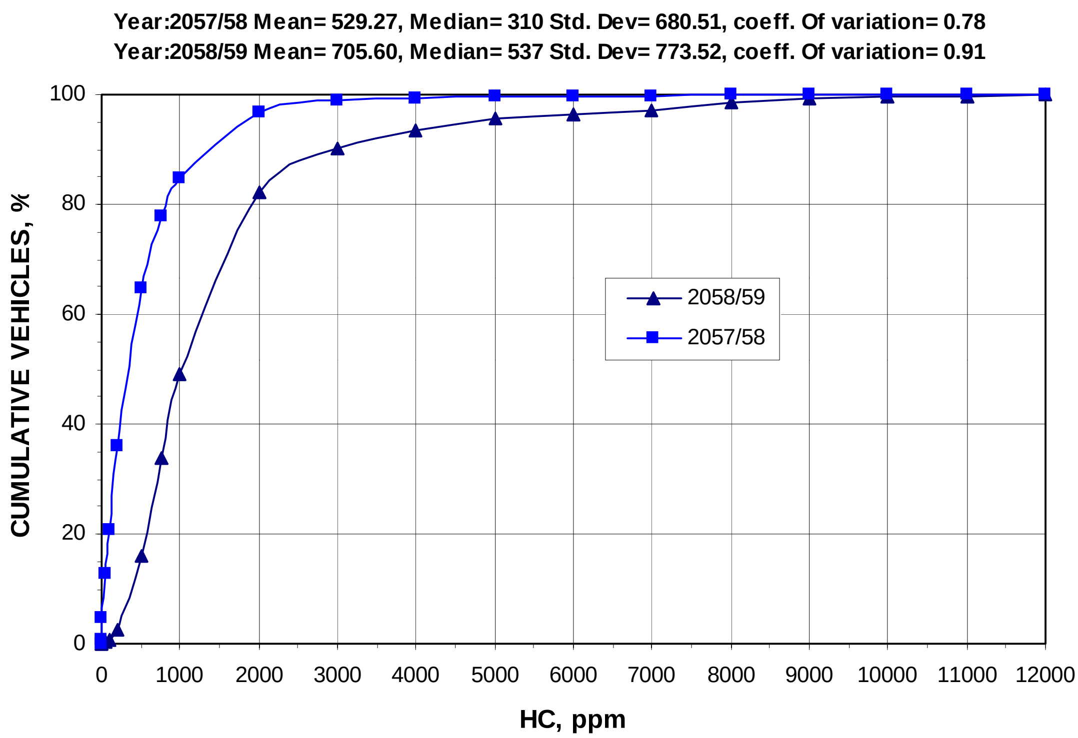

Figure 4.2.8 HC distribution from four wheelers in 2057/58 and 2058/59

CO and HC distribution by emission standard and by vehicles age

There are two emission standards, one for the vehicles of model year up to 1980 and another for the vehicles of model year from 1981 onward. Figures 4.2.9 and 4.2.10 show the CO and HC distribution for two model groups (up to 1980 and from 1981) equivalent to two groups of vehicles ages (20 years above and 20 years below).

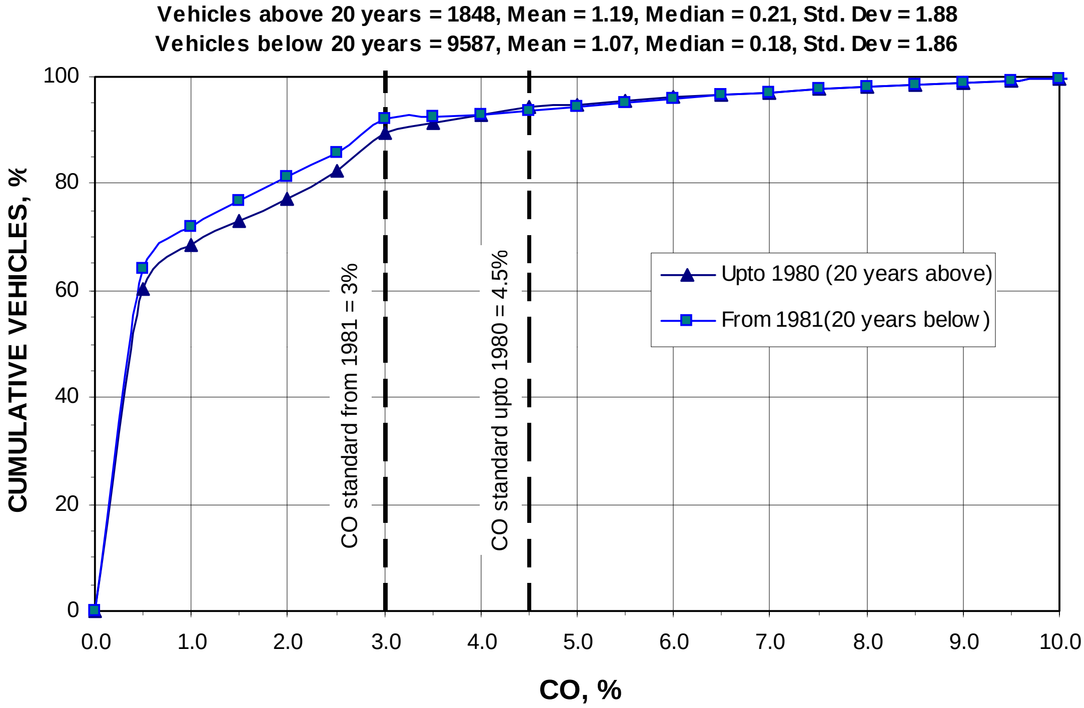

Figure 4.2.9 CO distribution from four wheelers by model year up to 1980 and from 1981 in 2057/58

Though the distribution of CO and HC emission is little bit lower for the vehicles up to model 1980 (20 years above), but it is not quite significant. Very high percentage of vehicles of both model groups is within the emission standard for both CO and HC. Almost 92% of the vehicle from model year 1981 onward (20 years below) and 89% of the those model year up to 1980 (20 year above) are within the 3% CO standard while the CO standard for vehicles model year up to 1980 was 4.5 %. Similarly, 85% of the vehicles from model year 1981 and 78% of the vehicles of model year up to 1980 are within the 1000 ppm HC standard. Hence, it is clear that the vehicles of these two group models or ages are showing their emission distributions are not very different from each other.

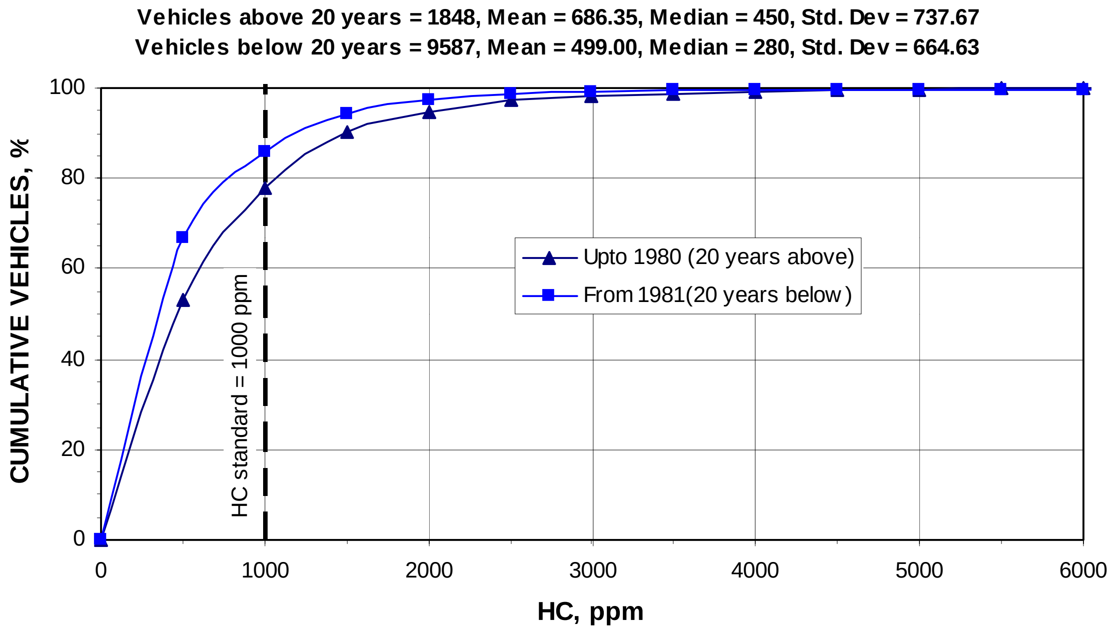

Figure 4.2.10 HC distribution from four wheelers by model year up to 1980 and from 1981 in 2057/58

CO and HC distribution by category and type

The four wheelers are divided into various categories and the comparative cumulative distributions of CO and HC are shown in Figures 4.2.11 and 4.2.12 respectively.

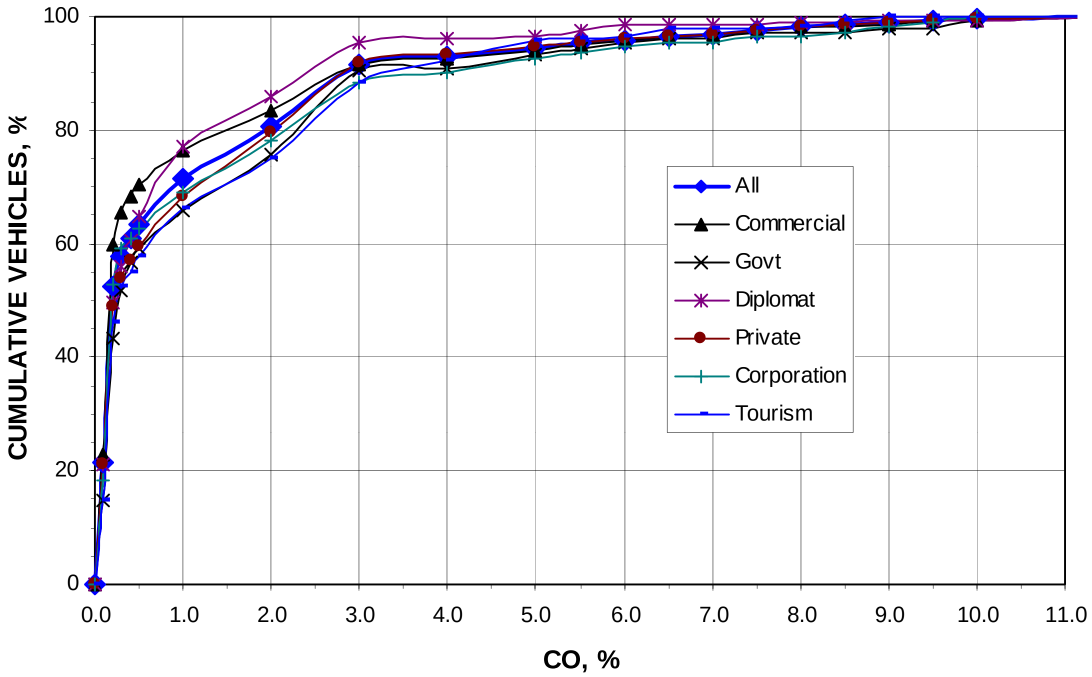

Figure 4.2.11 CO distribution from four wheelers by category in 2057/58

From the comparative distributions of various categories of the vehicles, it is seen that the tourism vehicles are producing more CO and HC emissions and the diplomatic vehicles are least emitting among all the groups. At 3% CO, 88% of the tourism vehicles are within standard while 95 % of the diplomatic vehicles are meeting the standard. Similarly, 78% of the vehicles of tourism category are within the 1000 ppm HC standard while 88% of the diplomatic vehicles are within the same standard. All the other categories fall between these two groups. However the difference is not too large and the distribution are similar.

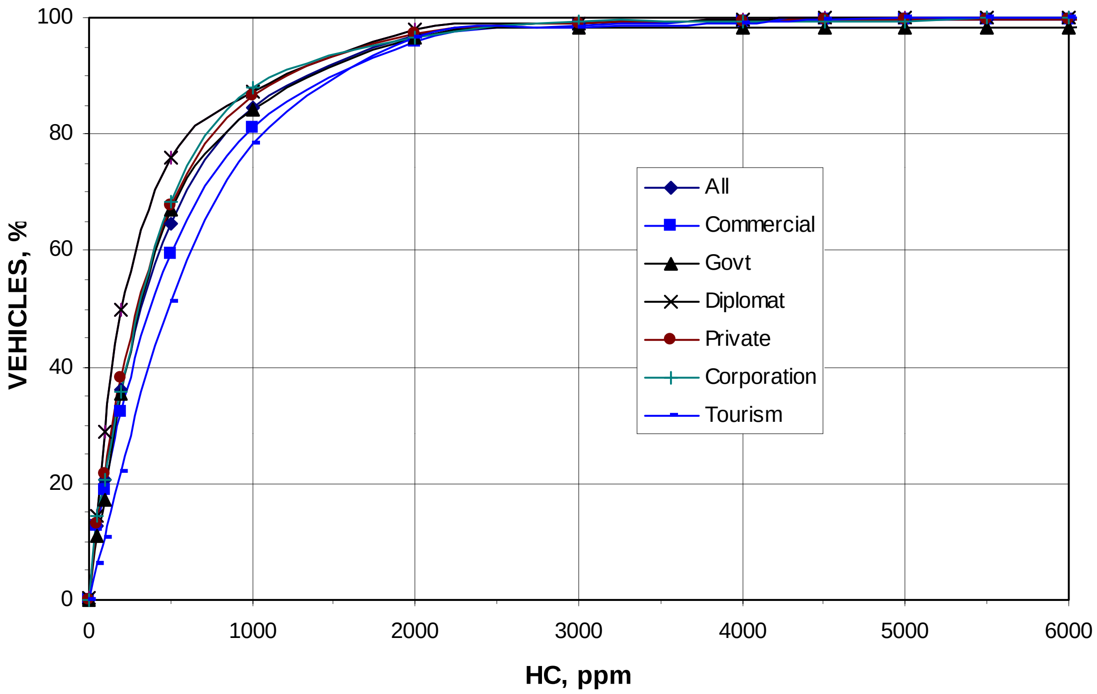

Figure 4.2.12 HC distribution from four wheelers by category in 2057/58

Likewise the vehicles are also divided into three types: car, van and jeep. The comparative studies of distribution of CO and HC emissions of four wheelers by type have also been done and are shown in Figures 4.2.13 and 4.2.14 respectively. The distributions of car, van and jeep are almost similar to each other undergoing the similar pattern. Almost 92 % of vehicles of all the above types are within the 3% CO emission standard and 85 % of all fall within the HC emission standard. They are not quite differentiated in emission distribution.

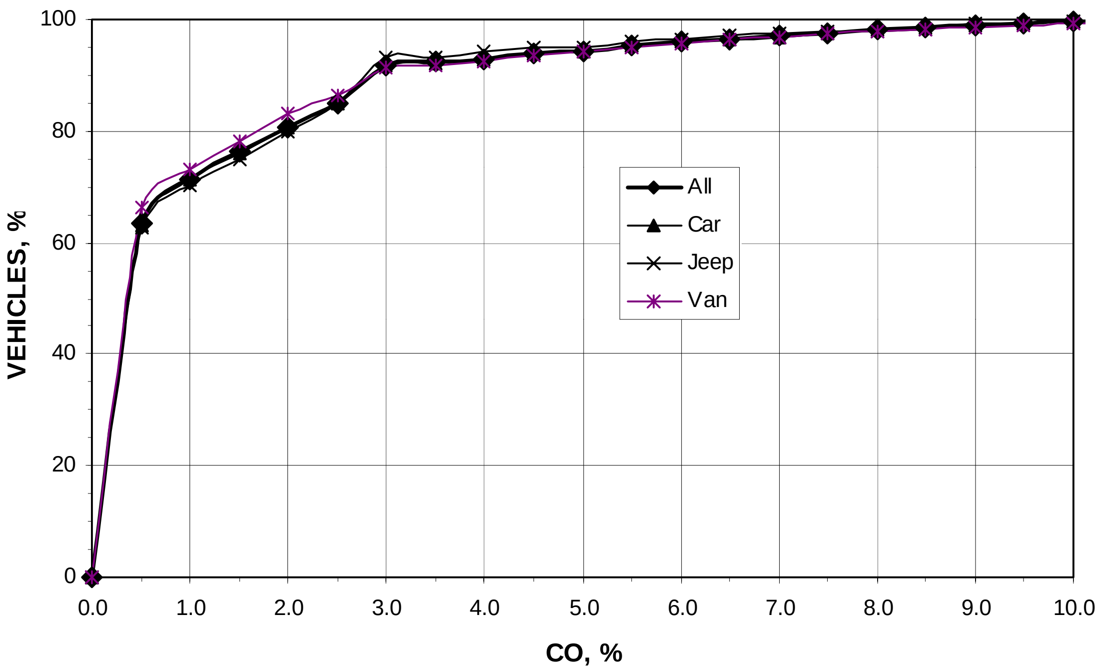

Figure 4.2.13 CO distribution from petrol four wheelers by type in 2057/58

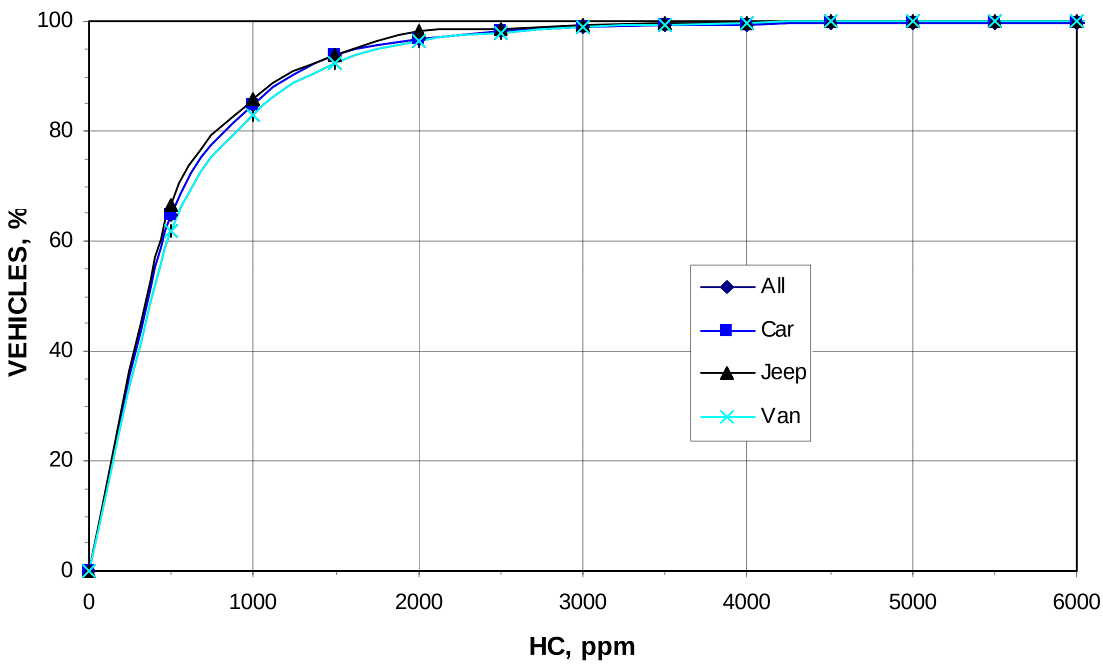

Figure 4.2.14 HC distribution from the petrol four wheelers by type in 2057/58

Cumulative distributions of emissions

Cumulative distributions of CO and HC emissions from four wheelers are shown in figures 4.2.15 to 4.2.18 respectively. 50% of the CO emission is caused by 10% of the vehicles in 2057/58 and the same percentage of emission is caused by 12% in 2058/59. Similarly, 50% of HC emission is caused by 15% of the vehicles in 2057/58 and 20% of the vehicles in 2058/59.

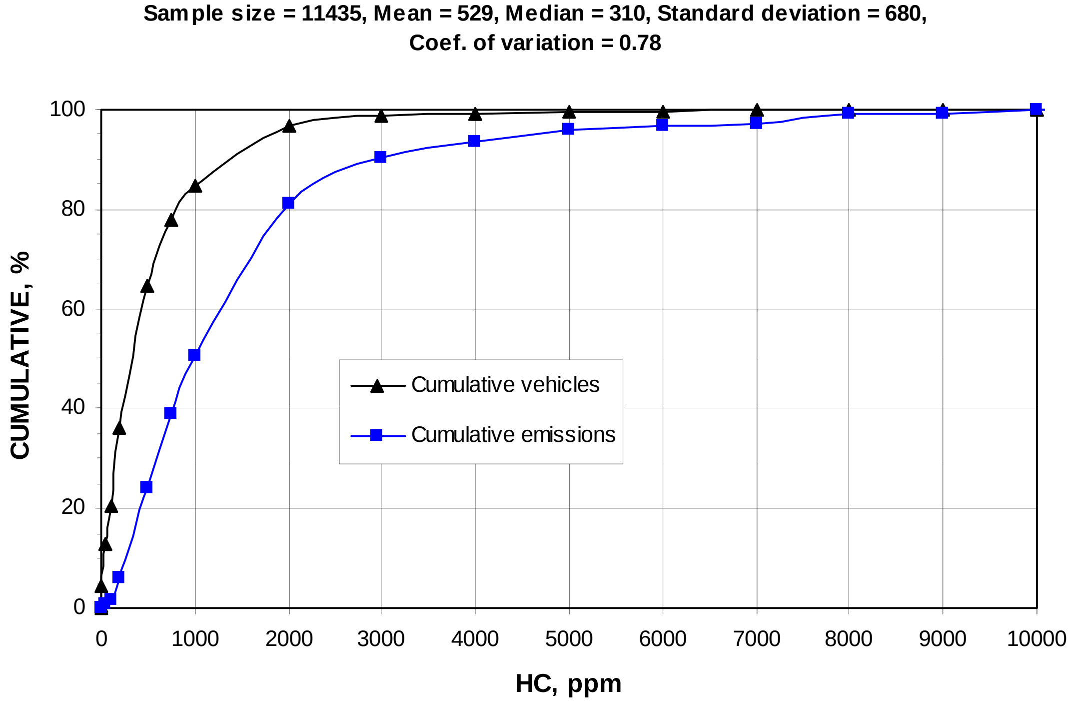

Figure 4.2.15 Cumulative distribution of HC emission from four wheelers in 2057/58

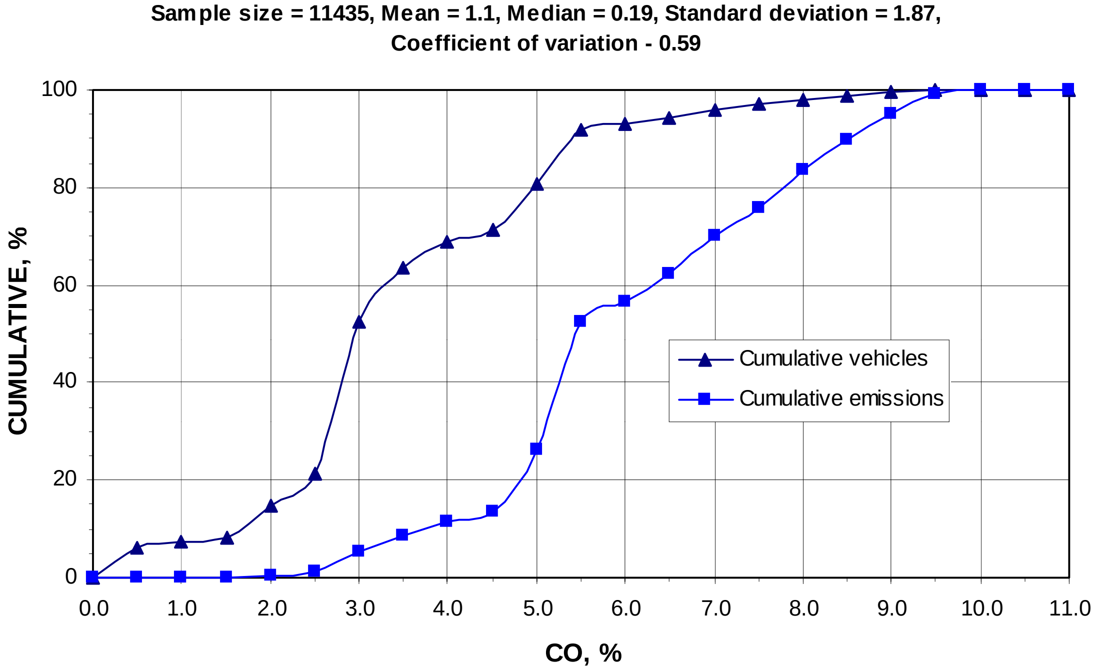

Figure 4.2.16 Cumulative distribution of CO emission from four wheelers in 2057/58

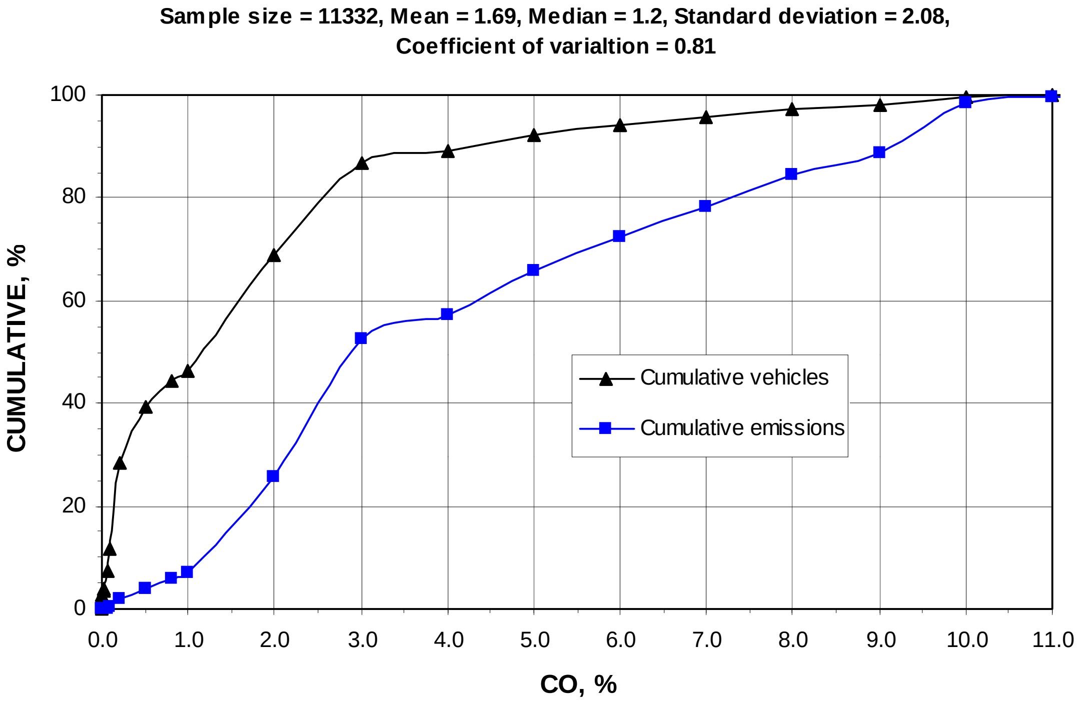

Figure 4.2.17 Cumulative distribution of CO emission from four wheelers in 2058/59

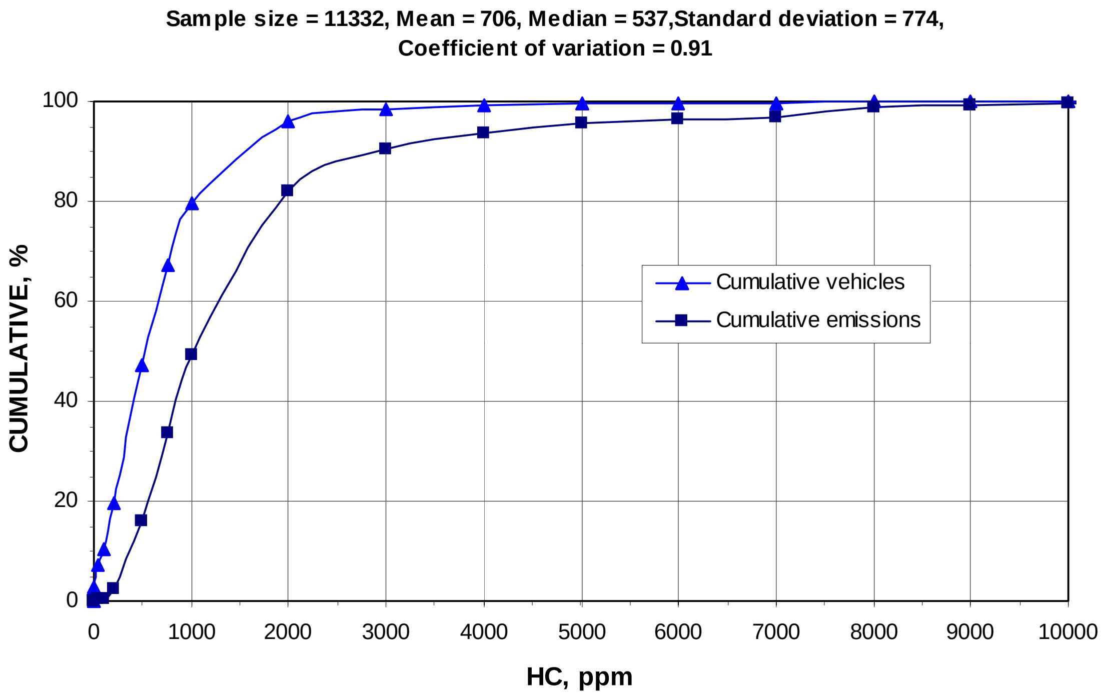

Figure 4.2.18 Cumulative distribution of HC emission from four wheelers in 2058/59

Vehicles before and after repair

When the vehicles get failed in the emission test, then it should again go back to test after some days having repaired the vehicle and get green sticker in the emission test. The data of the vehicles that were failed at the first time and get repaired and passed after sequence of times are taken to see if there is considerable decrease in the emission after the vehicles get repaired. The average CO and HC emissions of the four wheeler vehicles before and after repair are shown in Figures 4.2.19 and 4.2.20 respectively. It is quite clear that there is considerable decrease in both the emissions after the vehicles are repaired.

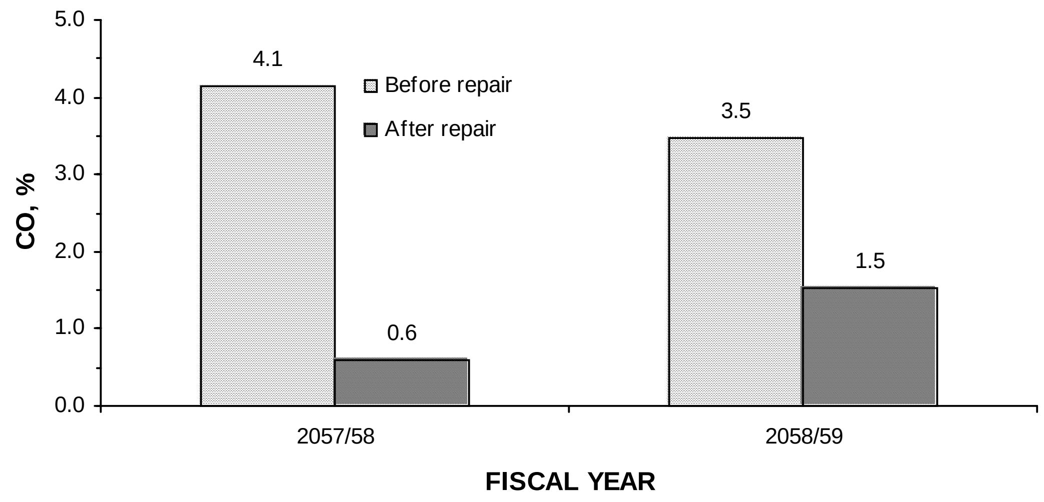

Figure 4.2.19 Average CO from petrol four wheelers before and after repair

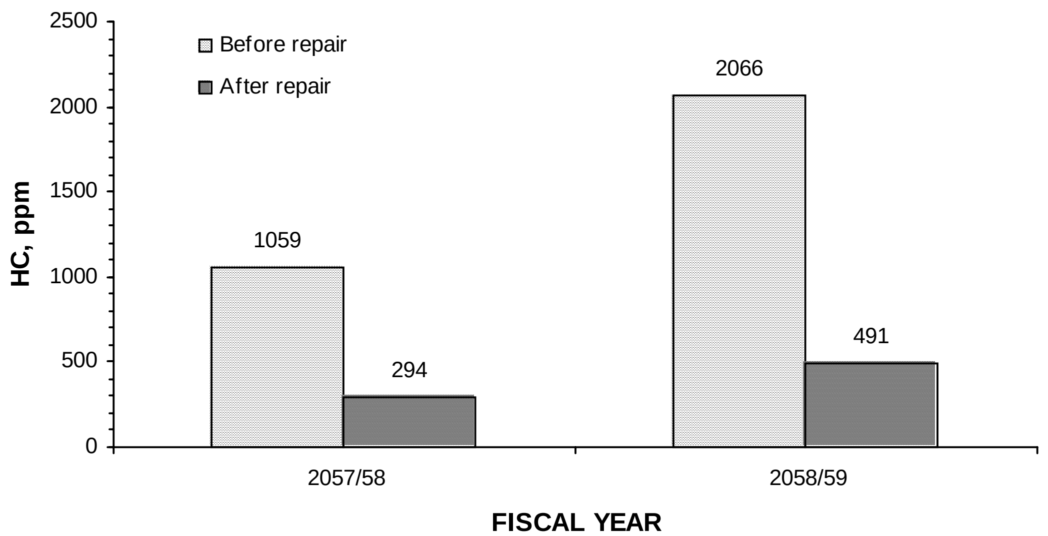

Figure 4.2.20 Average HC from petrol four wheelers before and after repair

Average CO and HC recorded in DoTM and KVTP

In the fiscal year 2058-59, emission tests from petrol vehicles of model year from 1998 to 2001 were conducted at Department of Transport Management (DoTM) and Kathmandu Valley Traffic Police (KVTP). Vehicle owner had choice to go to DoTM or KVTP for emission test. Altogether 3431 petrol vehicles (four wheelers) were undergone emission test at DoTM and 1926 at KVTP respectively (Figure 4.2.21).

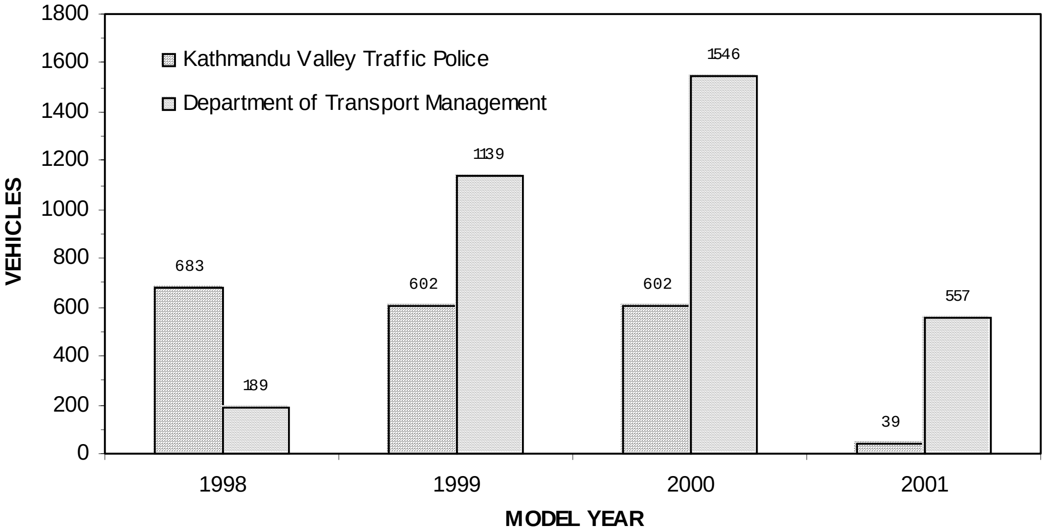

Figure 4.2.21 Petrol vehicles undergone emission test at KVTP and DoTM in 2058-59

The average values of CO and HC from these vehicles measured at these stations are presented in Figure 4.2.22 & 4.2.23.

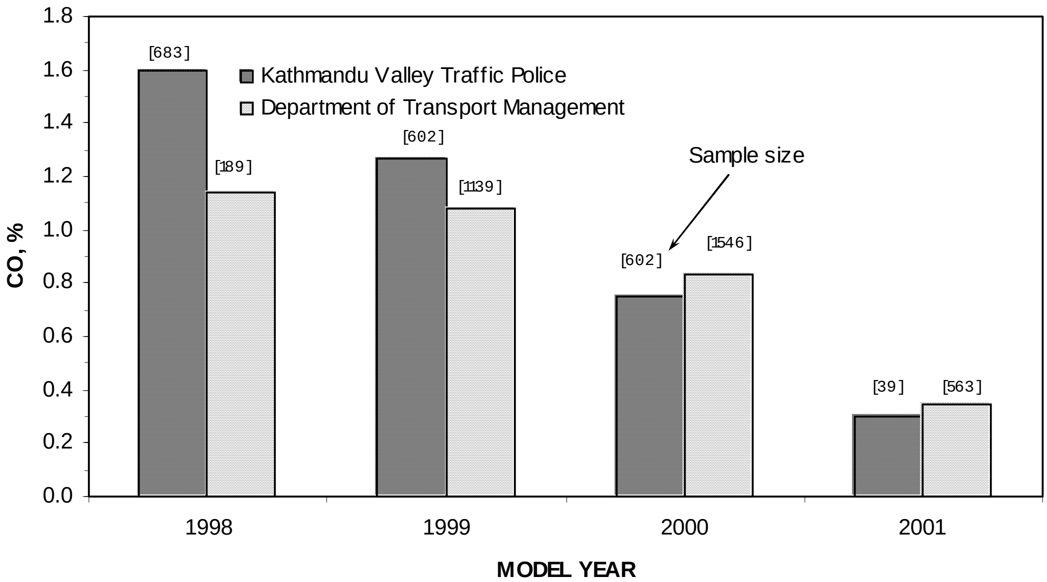

Figure 4.2.22 Average CO measured at DoTM and KVTP from petrol vehicles in 2058-59

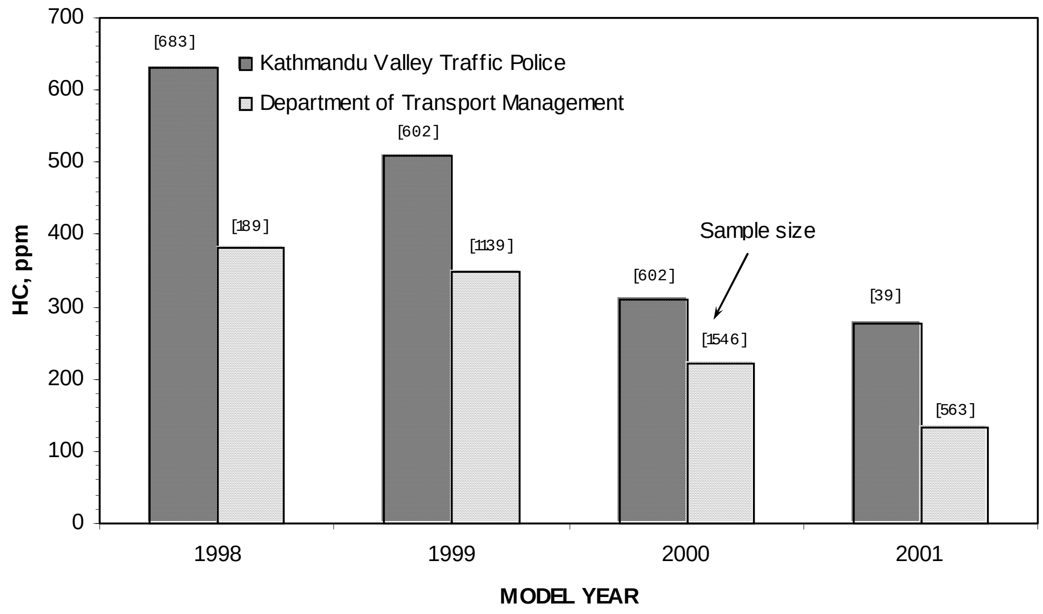

Figure 4.2.23 Average HC measured at DoTM and KVTP from petrol vehicles in 2058-59

Test of significance for difference of means

Significance test for difference of mean values of CO and HC emissions from petrol vehicles (four-wheeler) measured at two stations in the fiscal year 2058-59 were carried out for each model year using Z-test at 5% level of significance. For model year from 1999 to 2001 the average CO measured from petrol vehicles at DoTM did not differ significantly from the average CO measured from the petrol vehicles of same model year at KVTP. But there was significant difference in the mean value of CO for model year 1998. In the case of HC emissions the mean values HC measured from the petrol vehicles at these two stations varied significantly for all the model year. This indicates that the petrol vehicles undergoing emission tests at DoTM are comparatively emitting lower emissions since large number of them are imported under EURO-I emission standard.

The following two figures show CO and HC distributions from four wheeler petrol vehicles (model year after 1981) in 2058-59. Almost 97% of vehicles undergoing emission test at DoTM are within the existing emission standard (3% of CO and 1000 ppm of HC). This may be due to higher number of latest model year vehicles are undergoing emission tests at DoTM.

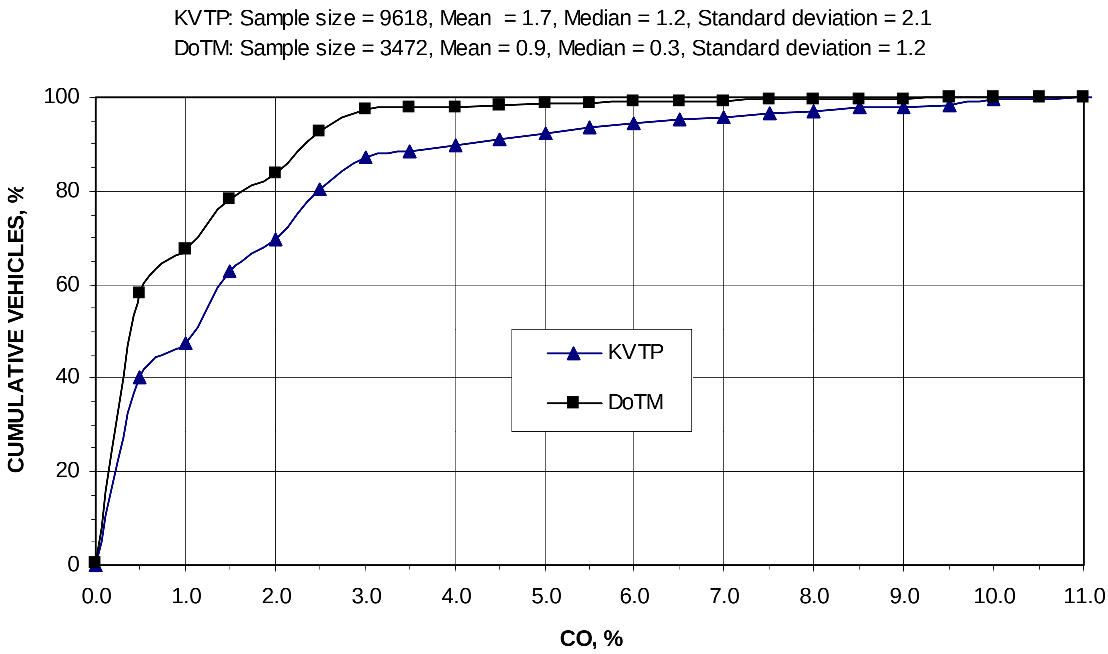

Figure 4.2.24 CO distribution from four wheeler petrol vehicles in 2058-59

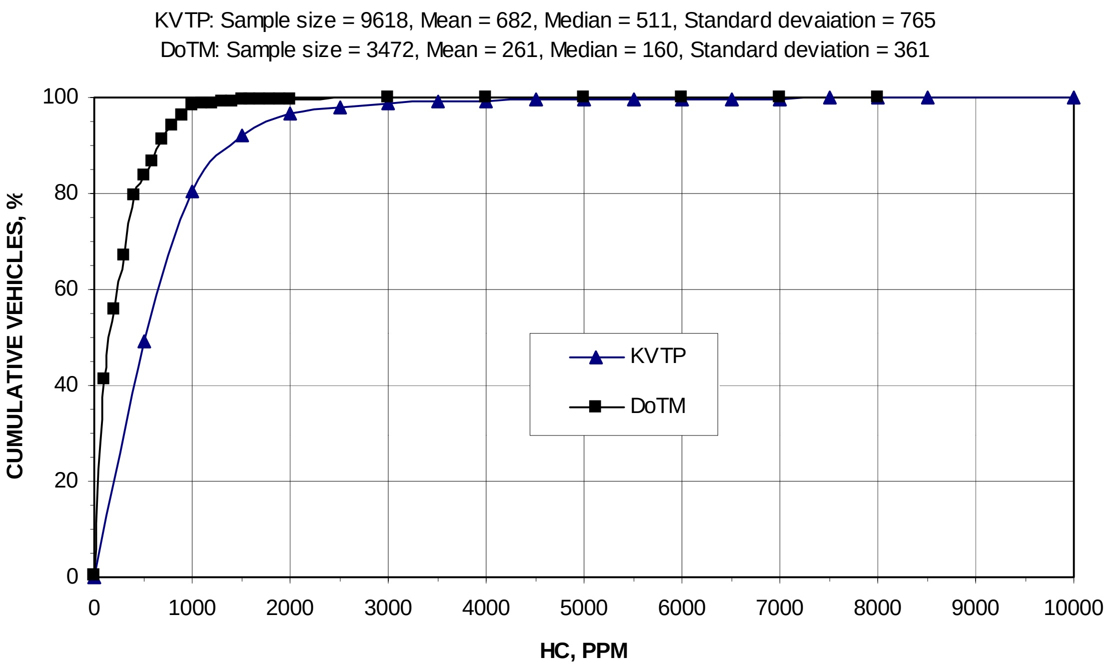

Figure 4.2.25 HC distribution from four wheeler petrol vehicles in 2058-59

In general vehicles with model year up to 1998 go to KVTP for emission test and after model year 1999 go to DoTM. Fiscal year 2058-59 being a transition period there is overlapping.

4.3 Diesel vehicles

The sample sizes of diesel vehicles undergone smoke test were 3450, 4945 and 4063 in 2057, 2058 and 2059 respectively. Highest percentage of failure rate was observed in the model year group of 1995 to 2000. This group consisted of maximum number of vehicles (Figure 4.3.1). Similar trends were observed in the year 2058 and 2059 (Appendix D).

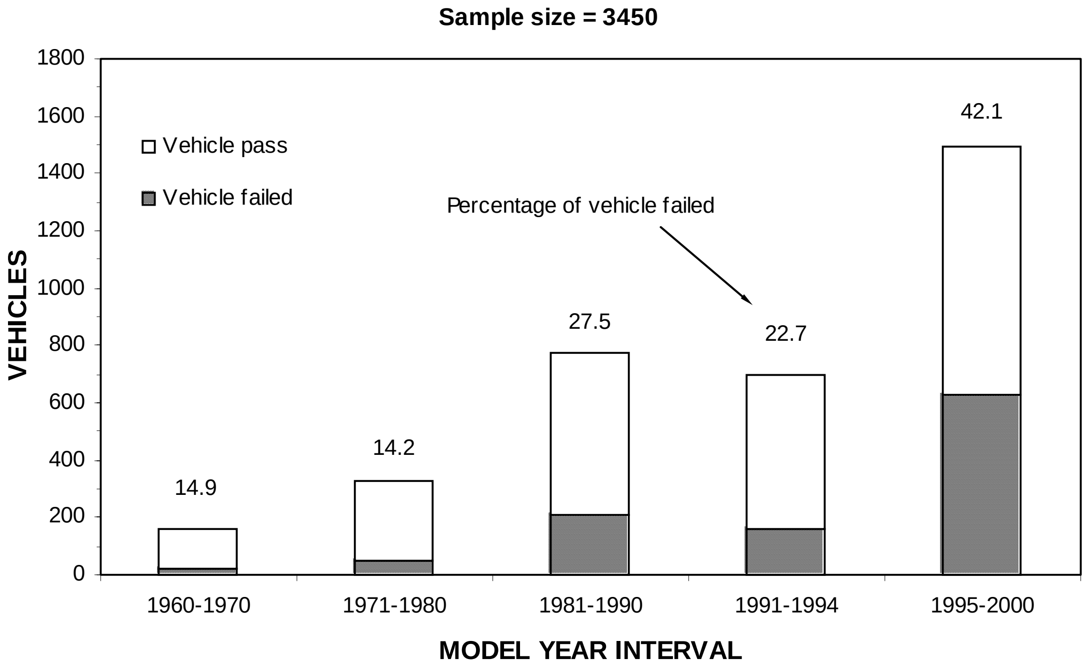

Figure 4.3.1 Percentage of diesel vehicles by model year failed in 2057

Average HSU

The average values of HSU from diesel vehicles lie in between 65% to 78% in 2057. The results indicate that all diesel vehicles produce smoke close to existing emission standards. Almost all the vehicles with model year up to 1994 are meeting the HSU standard equal to 75%. Most of the vehicles with model year after 1995 are exceeding the existing emission standard of 65% HSU (Figure 4.3.2). Comparatively better results are found in the year 2058. The smoke emissions of latest model year are found worse than the older model year vehicles when measured in k value in 2059 (Appendix D).

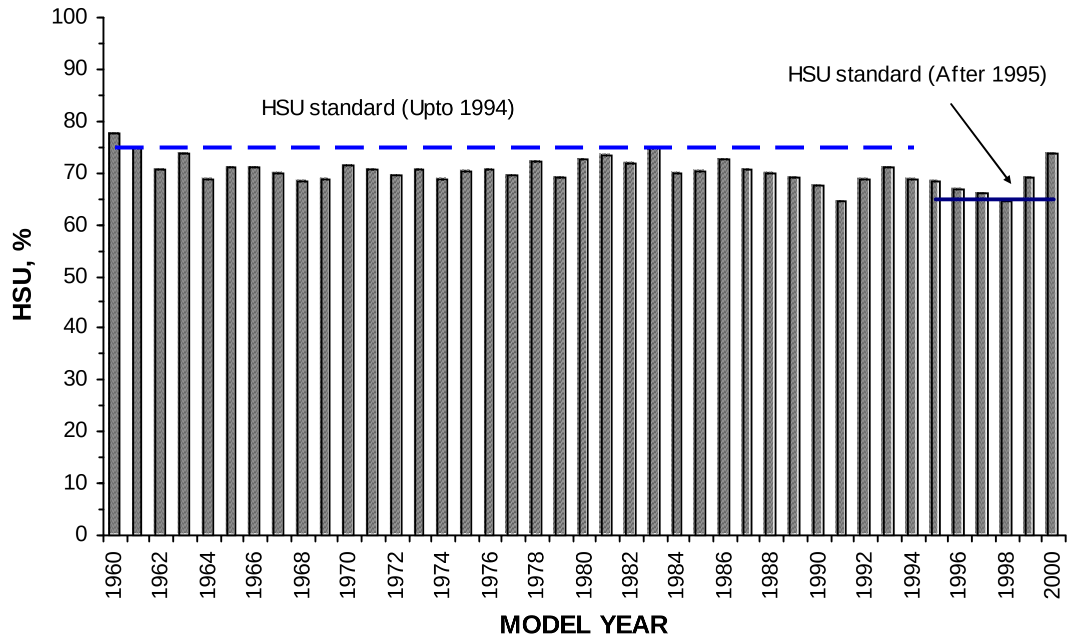

Figure 4.3.2 Average HSU distribution from diesel vehicles by model year, 2057

Highest percent of diesel vehicles contribute smoke emission in the range of 70-75% HSU (Figure 4.3.3). About 16% of vehicles are emitting HSU in the range of 60-65%. There are gross polluters which fall even in the range of 95-100% HSU. Similar results are observed in 2058 and 2059 (Appendix D).

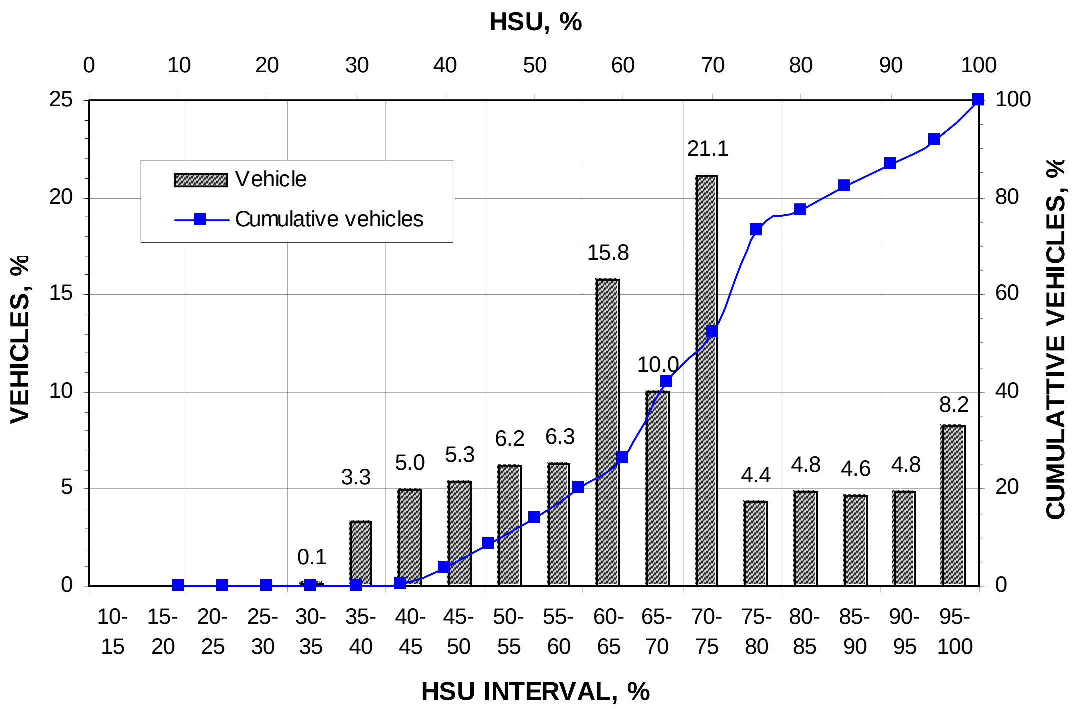

Figure 4.3.3 HSU distribution from diesel vehicles in 2057

Cumulative distribution of emission

Cumulative distribution of HSU emission indicates that about 40% of diesel vehicles are contributing 50% of HSU emission in 2057 (Figure 4.3.4). Similar trend was also observed in 2058. But the percentage of gross polluting diesel vehicles has been decreased to about 25% in 2059 (Figure 4.3.5).

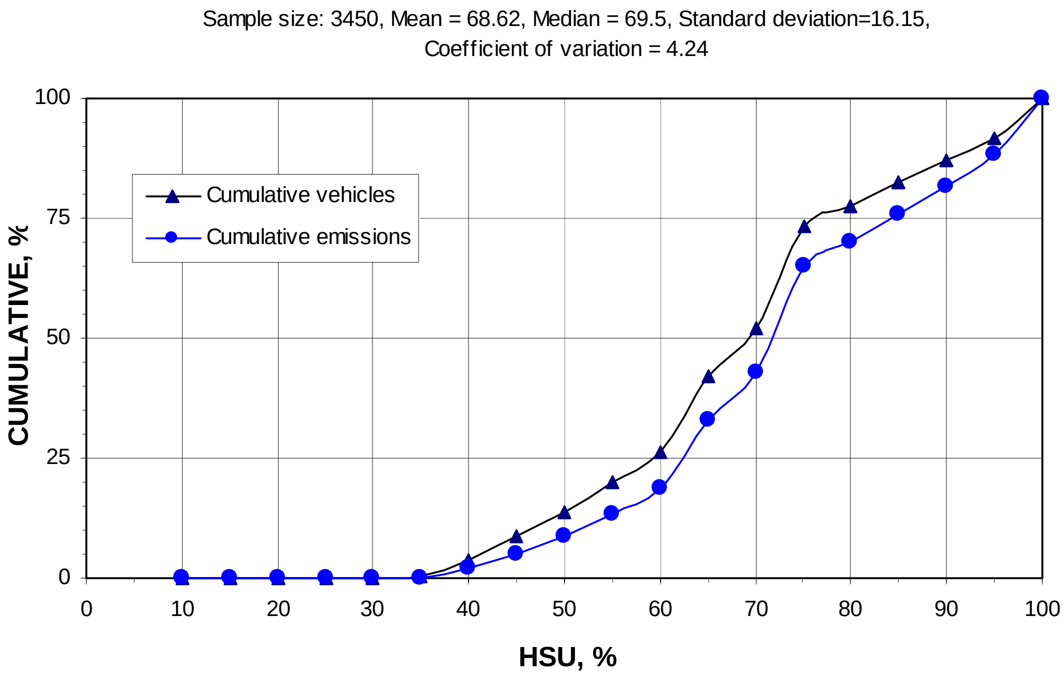

Figure 4.3.4 Cumulative HSU distribution from diesel vehicles in 2057

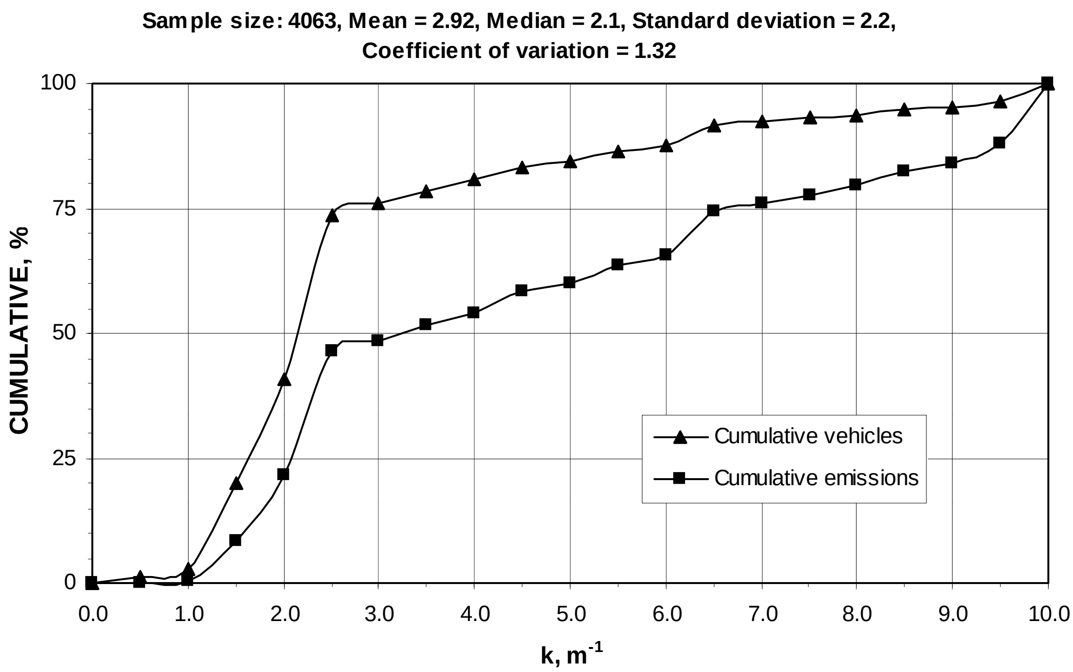

Figure 4.3.5 Cumulative HSU distribution from diesel vehicles in 2059

HSU distribution by category

The cumulative distributions of diesel vehicles by category reveal that diplomatic vehicles are producing least smoke and commercial vehicles are emitting the highest amount in 2057.

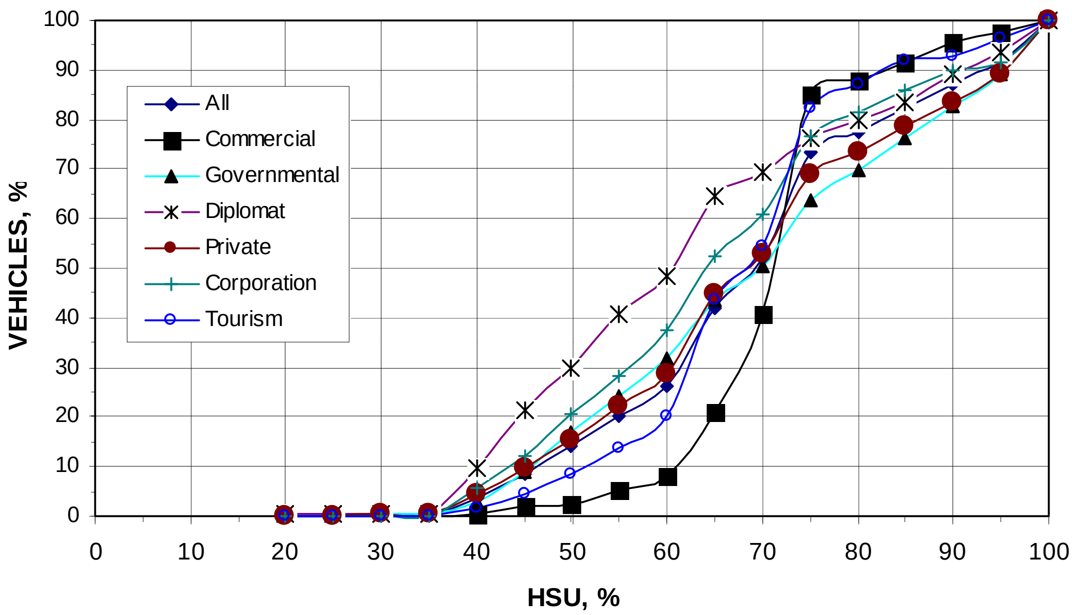

Figure 4.3.6 Cumulative HSU distribution from diesel vehicles by category in 2057

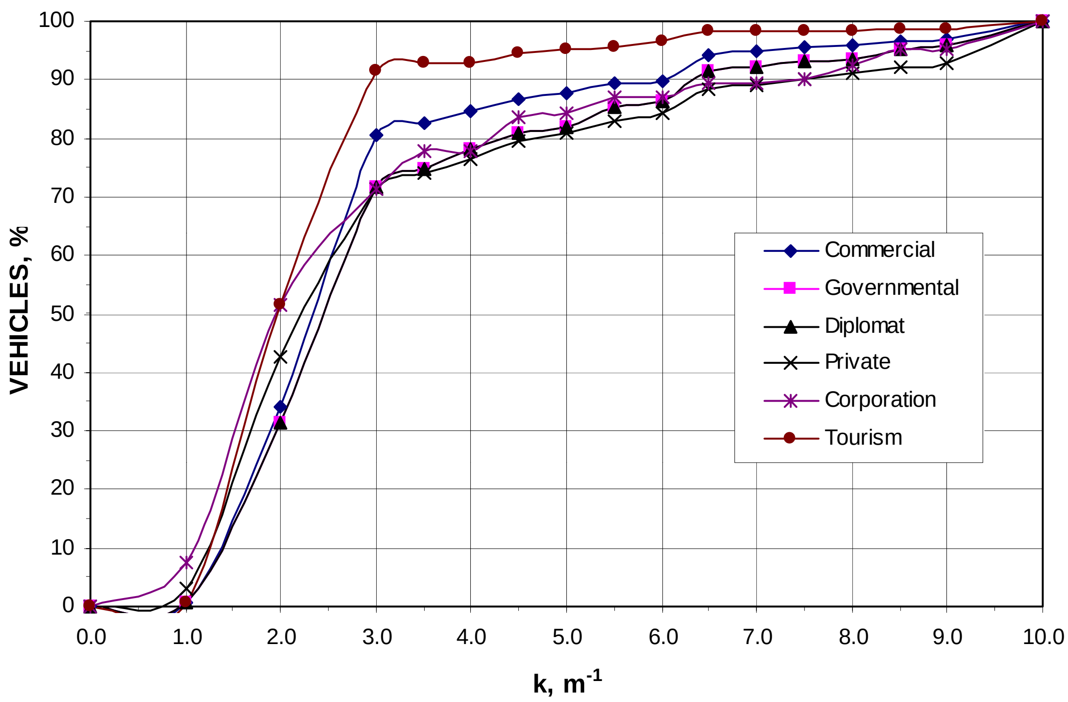

Figure 4.3.7 Cumulative k distribution from diesel vehicles by category in 2059

For example; 65% of HSU (which is the emission standard for diesel vehicles of model year after 1995) was contributed by 65% of the diplomatic vehicles, 55% of corporation vehicles, 45% each of private, government and tourism vehicles and 20% of commercial diesel vehicles respectively (Figure 4.3.6). This may be due to the fact that majority of diplomatic vehicles are of latest model year whereas the commercial vehicles are comprised of older model years. Similar trends of HSU distribution were observed in 2058. 74% of diesel vehicles belonging to tourism category has met 2.5 m^{-1} k value in 2059 followed by 64% of corporation vehicles, 58% private and commercial vehicles each and 52% of government and diplomatic vehicles (Figure 4.3.7). These results differ from the results of emission from diesel vehicles in previous two years when smoke measurement unit was switched from HSU to k value.

HSU distribution by type

HSU distribution by different types of diesel vehicles is presented in Figure 4.3.8. 50% of car population meets the HSU emission standard of 65% and only 24% of minibuses meet this standard in 2057. This may be because of higher number of minibuses belonging to model year up to 1994 having emission standard equal to 75% HSU. In 2058, the overall smoke emission from all types of diesel vehicle decreased in comparison to HSU emission in 2057.

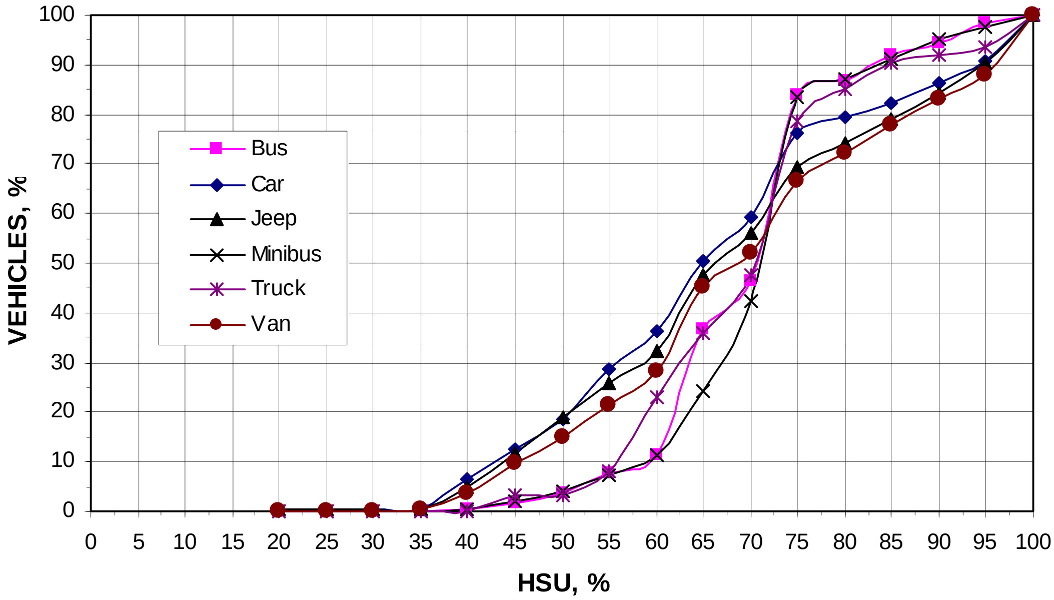

Figure 4.3.8 Cumulative HSU distribution from diesel vehicles by type in 2057

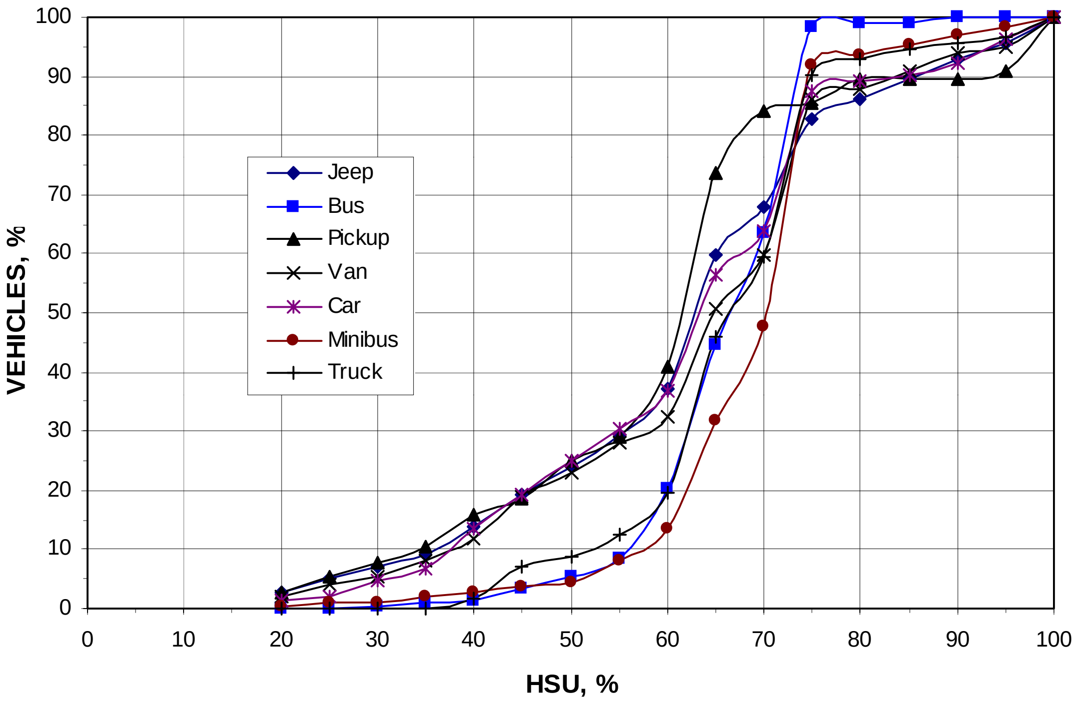

Figure 4.3.9 Cumulative HSU distribution from diesel vehicles by type in 2058

For example; 74% of pick up, 60% of jeep, 56% of car, 51% of van, 46% of truck, 44% of bus and 32% of minibus meet the emission standard of 65% HSU.

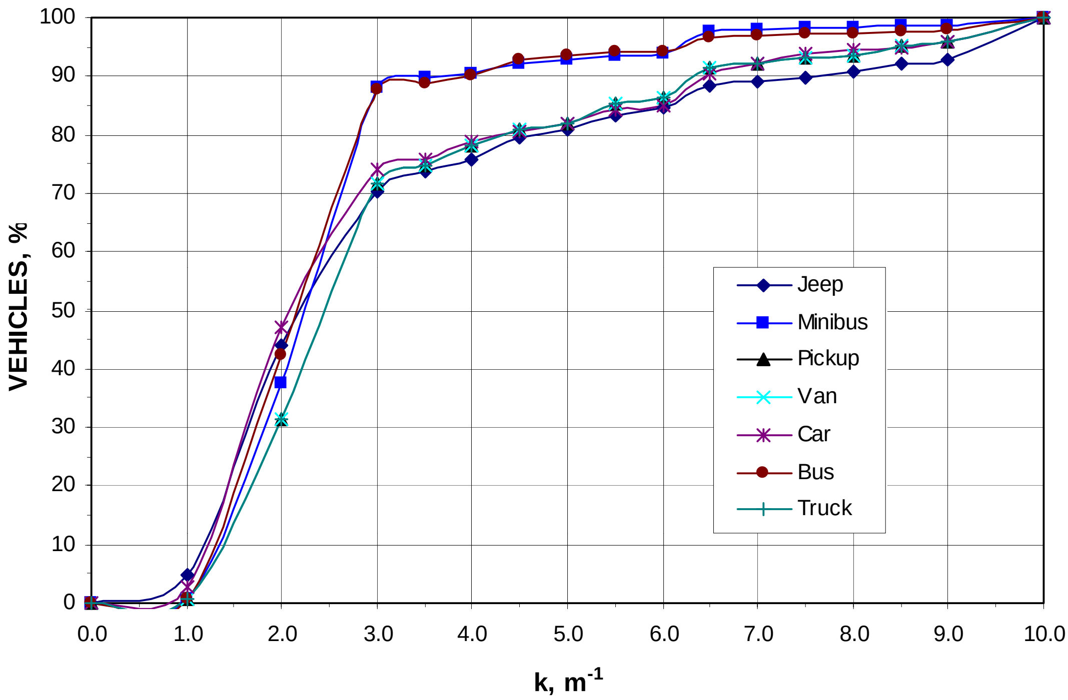

Figure 4.3.10 Cumulative k distribution from diesel vehicles in 2059

In 2059 the smoke emission was measured in k values with opacimeter and the results of 4063 sample size consisting of different types of diesel vehicles are presented in Figure 4.3.10. As it can be seen from the figure about 66% of bus, 64% of car and minibus each, 58% of jeep, 52% of pick up, truck and van each met the k value equal to 2.5 m^{-1}. In this year may be new buses must have added to the fleet.

HSU distribution by emission standard

There is a significant difference in HSU distribution between model year up to 1994 and after 1995 in 2057 as illustrated in Figure 4.3.11. About 58% of diesel vehicles of model year after 1995 met the emission standard of 65% HSU and about 78% of vehicle of model year up to 1994 met the set emission standard of 75% HSU. About 30% of vehicle of model year up to 1994 are emitting 65% HSU. There is not significant difference in k values measured for the model year up to 1994 and after 1995 in 2059 in both existing standard. Almost 75% of the total sample size of diesel vehicles met the emission standard of k value equal to 2.44 m^{-1} as shown in Figure 4.3.12. It indicates the better performance of diesel vehicles in 2059.

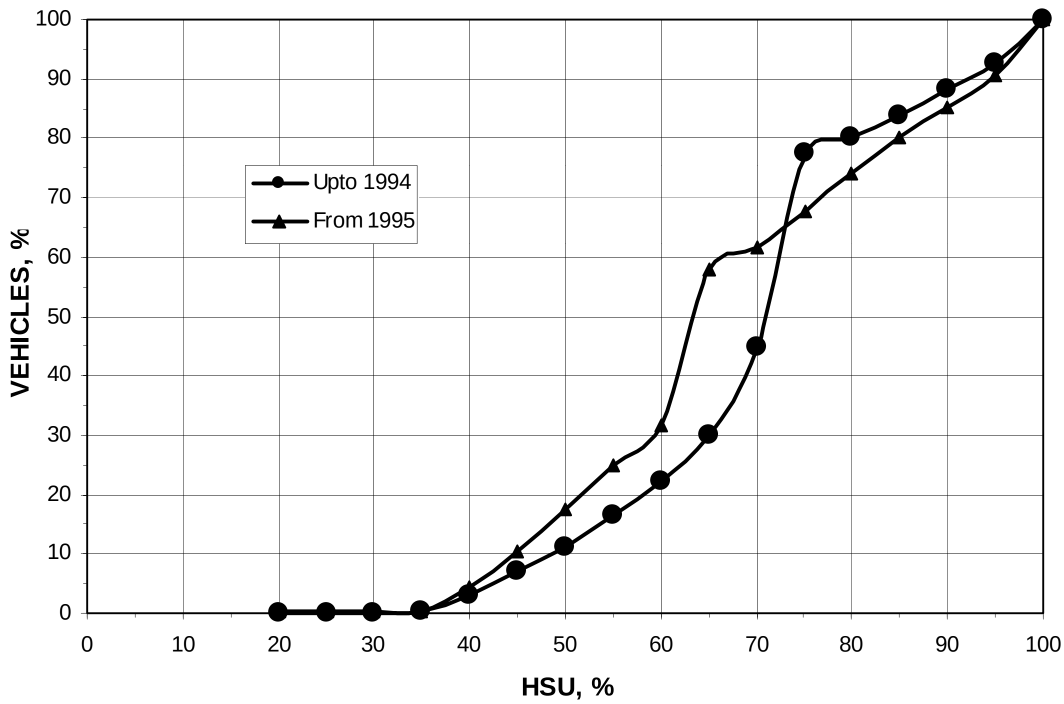

Figure 4.3.11 HSU distribution from diesel vehicles by model year up to 1994 and from 1995 in 2057

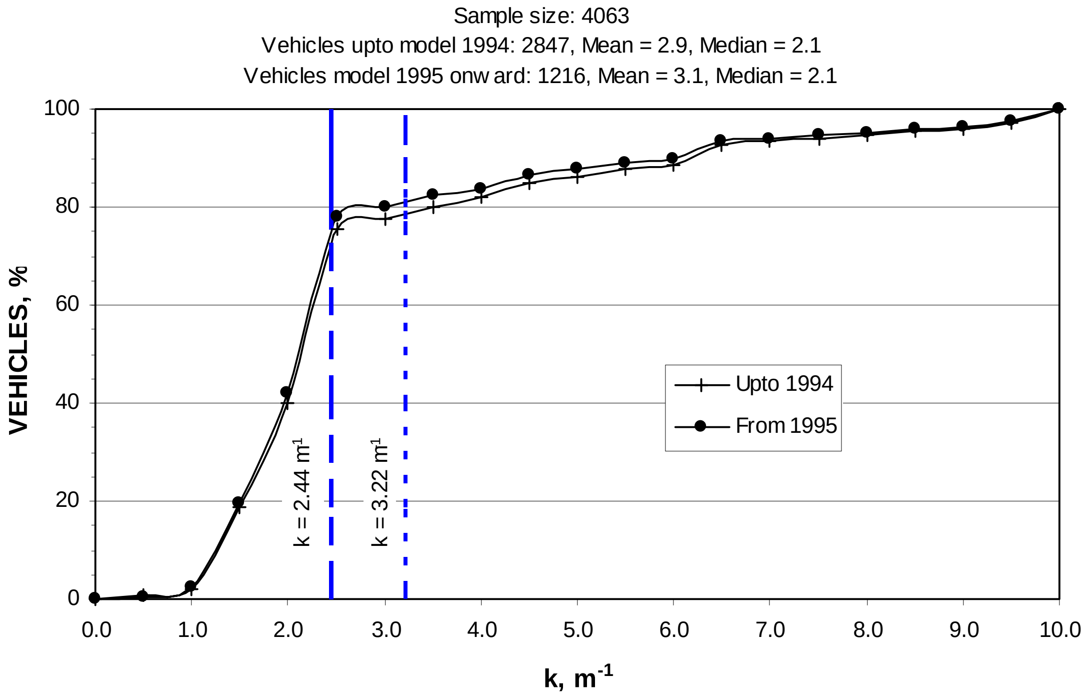

Figure 4.3.12 k value distribution from diesel vehicles by model year up to 1994 and after 1995 in 2059

HSU distribution by age

There is a significant difference of HSU distribution between 20 years older vehicles and 20 years below at two HSU emission standards (Figure 4.3.13). About 18% of the 20 years older vehicles are meeting emission standard of 65% HSU and 46% of 20 years below are meeting same standard. At 75% HSU, there are 71% of 20 years younger vehicles and 86% of 20 years older vehicles in 2057. Similar trends are also observed in the sample size of the diesel vehicles in 2058. On the contrary, 2.44 m^{-1} k is met by 72%of diesel vehicles, 20 years below in age and by 86% of diesel vehicles above 20 years in age. It might be due to little number of diesel vehicles belonging to that age group (Appendix D).

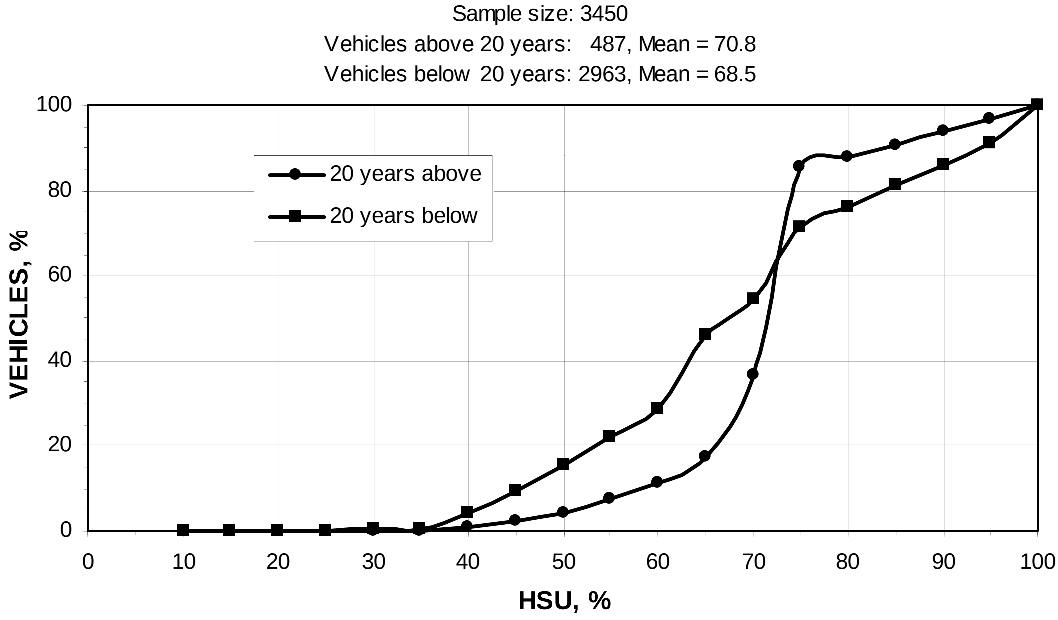

Figure 4.3.13 Cumulative HSU distribution from diesel vehicles by age in 2057

Effect of repair on emission

The average value of HSU emission from diesel vehicles is found reduced after repair in each test year. This is obvious and the reduction in average value of HSU was observed maximum in 2059 (Figure 4.3.14). The overall average value of HSU after repair lies in between 55 to 58 HSU.

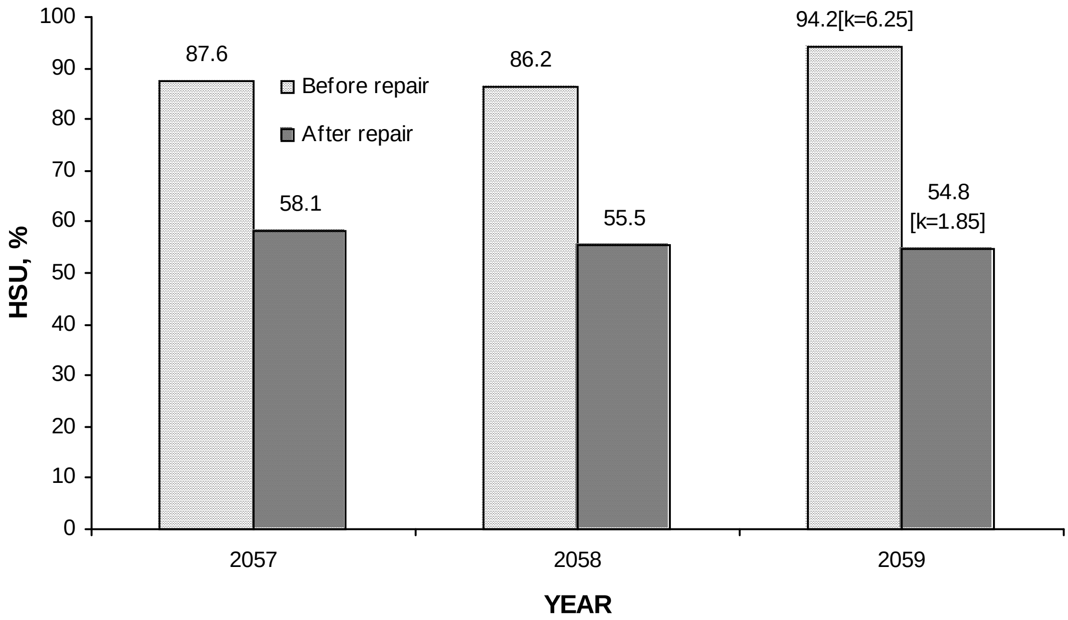

Figure 4.3.14 Average HSU emission from diesel vehicles before and after repair in different year.

The following two figures (Figures 4.3.15 & 4.3.16) show the indication of effectiveness of Inspection and Maintenance Program of the government. The cumulative distribution of vehicles with respect to smoke emission increased. For example, about 42% of diesel vehicles were emitting 65% HSU in 2057 and this value was increased to about 55% in 2058.

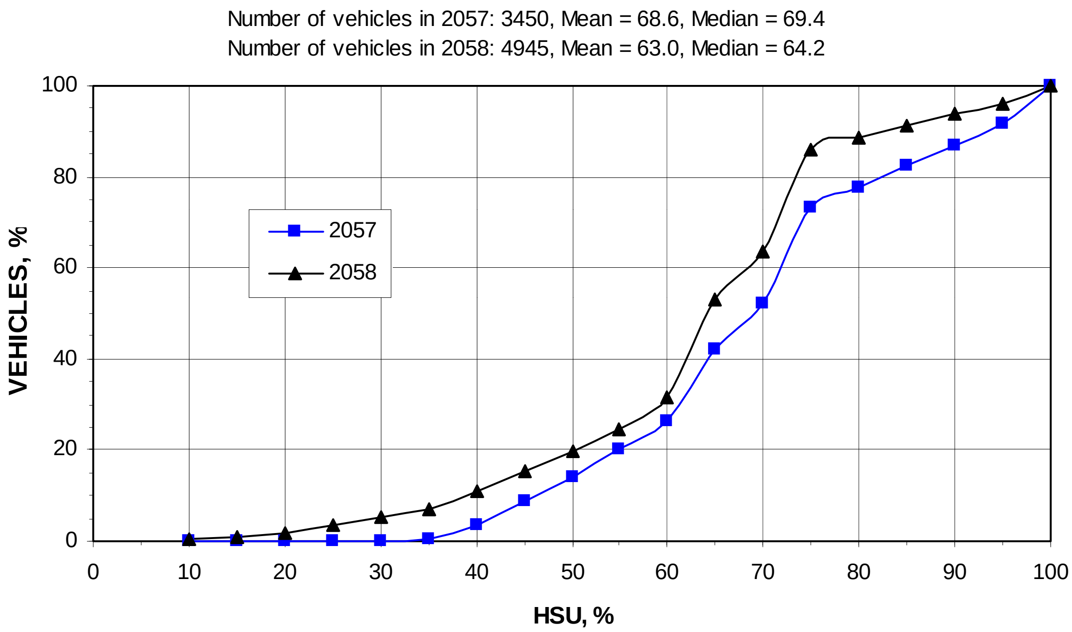

Figure 4.3.15 HSU distribution from diesel vehicles in the year 2057 and 2058

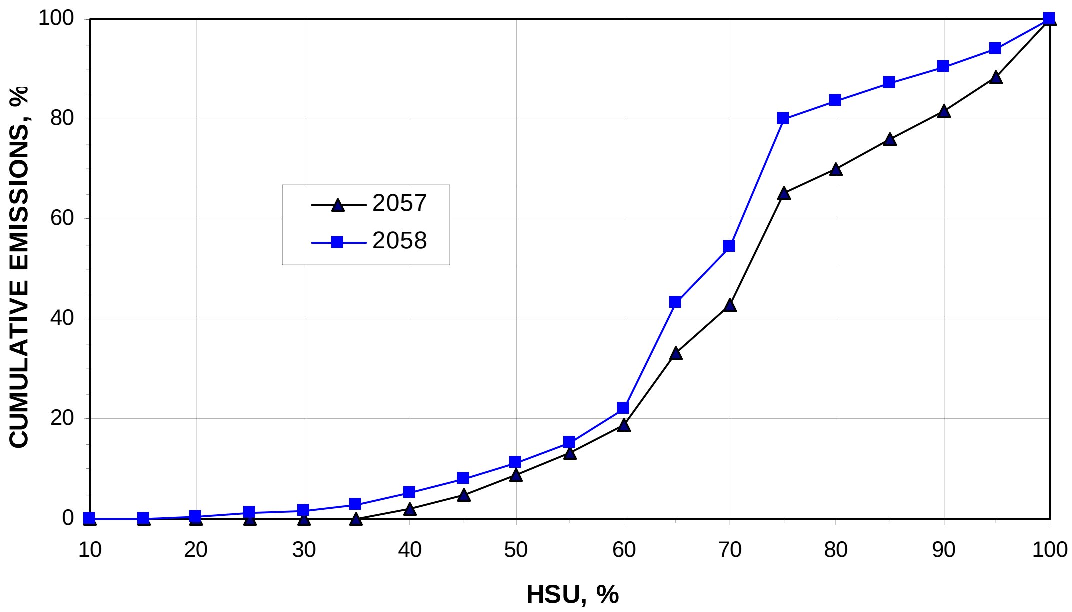

Figure 4.3.16 Cumulative HSU emission from diesel vehicles in 2057 and 2058

The sample size of vehicles was grouped as per model year and their emissions were compared with the existing emission standard for diesel vehicles after 1995 model year. The results are presented in the following Figures 4.3.17 and 4.3.18 respectively. Highest percentage of vehicles exceeding the standard was from group 1981-1990.

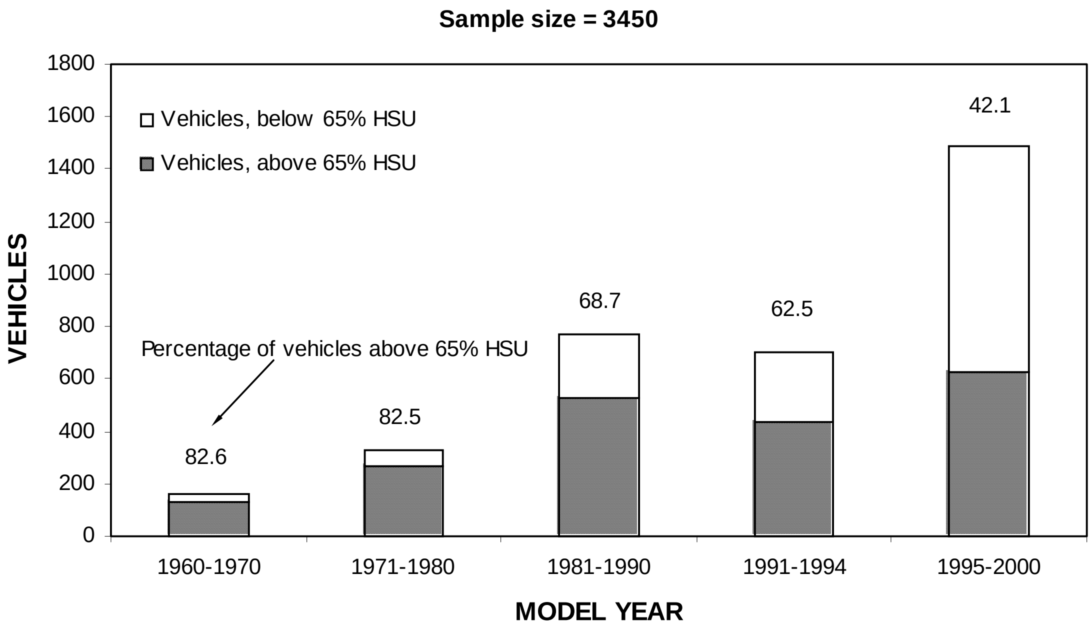

Figure 4.3.17 Percentage diesel vehicles by model year above 65% HSU in 2057

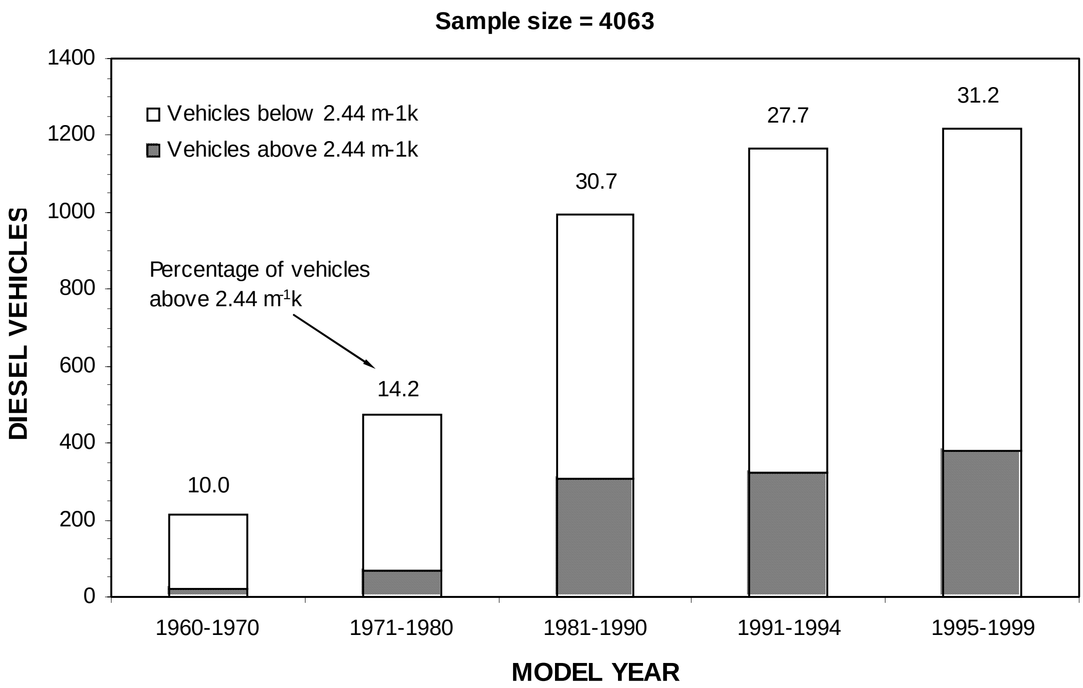

Figure 4.3.18 Percentage of diesel vehicles by model year above 2.44 m^{-1} k value in 2059

Average HSU recorded in DoTM and KVTP

In 2058, emission tests from diesel vehicles of model year from 1998 to 2001 were conducted at DoTM and KVTP. Vehicle owner had choice to go to DoTM or KVTP for emission test. Altogether 639 diesel vehicles were undergone emission test at DoTM and 946 at KVTP respectively. The average values of HSU from these vehicles measured at these stations are presented in Figure 4.3.19.

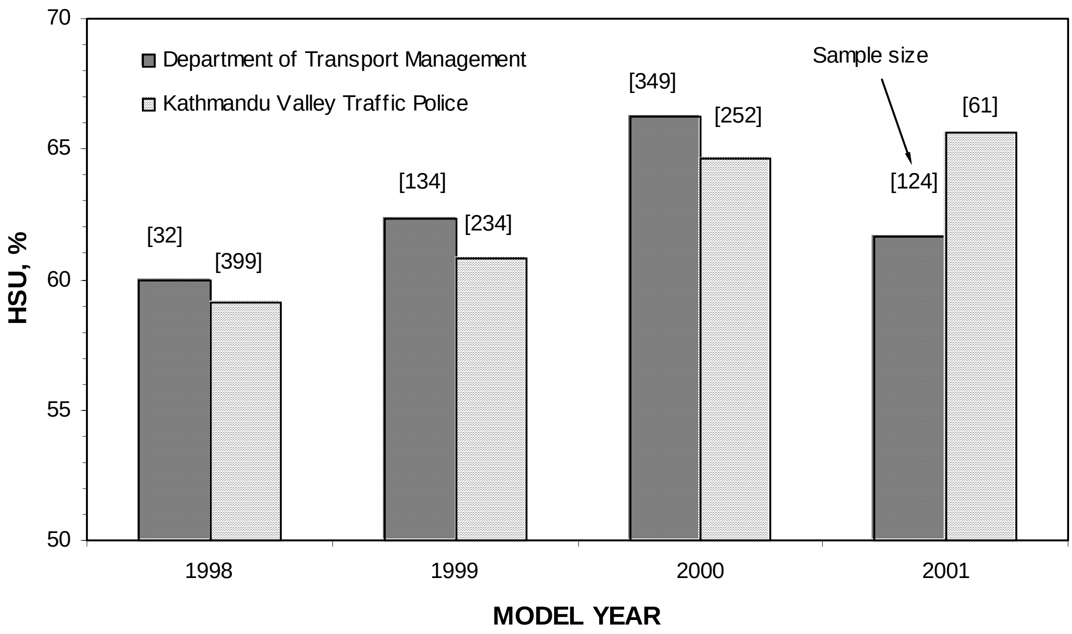

Figure 4.3.19 Average HSU from diesel vehicles measured at DoTM and KVTP

Test of significance for difference of means

Significance test for difference of mean values of HSU emissions from diesel vehicles measured at two stations in 2058 were carried out for each model year using Z-test at 5% level of significance. For model year from 1998 to 2001 the average HSU measured from diesel vehicles at DoTM did not differ significantly from the average HSU measured from the diesel vehicles of same model year at KVTP.

5. CONCLUSIONS

Three-wheelers

- Average CO emissions were 2.0% and 2.5% in 2057-58 and 2058-59 respectively. Both the values are less than the existing CO emission standard for three-wheelers. Similarly average HC emissions were 2198 ppm and 2631 ppm in 2057-58 and 2058-59 respectively. These values are less than existing standard (7800 ppm) for HC emission.

- About 80% of three-wheelers of model year up to 1991 and 93% of three-wheelers of model year after 1992 are emitting CO emission less than or equal to 3%. So a separate emission standard for CO emission as per model year is unnecessary and can be set only to one CO emission standard for three-wheelers.

- More than 80% of three-wheelers (both model year up to 1991 and after 1992) are producing HC emission less than 4000 ppm. It is therefore, essential to reduce HC emission standard for three-wheelers from 7800 ppm to less than 4000 ppm.

- There is not significant difference in distribution of CO and HC emission by age. That is, three-wheelers with 20 years old in age and 20 years below are contributing almost equal amount of emissions.

- The performance of private three-wheelers is better than commercial three-wheelers in terms of CO and HC emissions even though their total number is little. This indicates that private three-wheelers are better maintained than the commercial ones.

- Emission level of private three- wheelers increased from 2057-58 to 2058-59. For example, 2000 ppm HC emission is emitted by 70% of private three-wheelers in 2057-58 and the same amount of HC emission was produced by 57% of private three-wheelers in 2058-59 respectively.

- The number of gross polluting three-wheelers (in percent) is increased from 2057-58 to 2058-59. For example; 50% of cumulative CO emission is contributed by 26% of whole population of three-wheelers in 2057-58 and by 30% in 2058-59 respectively. Similarly 23% of three-wheelers have emitted 50% of HC emission in 2057-58 and 27% of three-wheelers have contributed the same percent of HC emission in 2058-59.

Four wheelers (car, jeep, van)

- Average CO emissions were 1.1% and 1.7% in 2057-58 and 2058-59 respectively. Both the values are less than the existing CO emission standard for four wheelers. Similarly average HC emissions were 529.3 ppm and 705.6 ppm in 2057-58 and 2058-59 respectively. These values are less than the existing standard (1000 ppm) for HC emission.

- About 89% of four-wheelers of model year up to 1980 and 92% of four-wheelers of model year after 1981 are emitting CO emission less than or equal to 3%. So a separate emission standard for CO emission as per model year is unnecessary and can be set only to one CO emission standard for four-wheelers.

- About 85% of the vehicles after model year 1981 and 78% of the vehicles up to model year 1980 are emitting HC emissions less than or equal to 1000 ppm.

- There is not significant difference in distribution of CO and HC emission by age. That is, CO and HC emissions emitted by four-wheelers with 20 years old in age and 20 years below are not much different.

- Vehicles belonging to tourism category are producing highest CO and HC emissions and diplomatic category are emitting lowest CO and HC emissions. Car, van and jeep are emitting similar amount of CO and HC emissions.

- In 2058-59, CO and HC emissions have increased more than in 2057-58.

- The number of gross polluting four-wheelers (in percent) is increased from 2057-58 to 2058-59. For example; 50% of cumulative CO emission is contributed by 10% of whole population of four-wheelers in 2057-58 and 15% in 2058-59 respectively. Similarly 15% of four-wheelers have emitted 50% of HC emission in 2057-58 and 20% of four-wheelers have contributed the same percent of HC emission in 2058-59.

Diesel vehicles

- The average smoke emissions from diesel vehicles were 68.6%HSU, 63% HSU and 2.92 m^{-1} k value (71% HSU equivalent) in 2057, 2058 and 2059 respectively. These values lie in between the existing standard 65% HSU for vehicles, model year up to 1994 and 75% HSU for vehicles, after model year 1995.

- Since the average values of smoke emission lie in between the existing emission standard only one emission value can be proposed. It can be average of these two standard values 70% HSU or fix to 65% HSU or k value equal to 3 m^{-1}.

- The number of gross polluting diesel vehicles has been decreased from 2057 to 2058. This is the positive indicator of effective Inspection and Management Program conducted by KVTP.

- Diesel vehicles belonging to diplomats and corporations had lower emission level than commercial and private vehicles in 2057 and 2058. But in 2059 it did not show comparatively better results than other categories.

- Minibuses are producing more smokes compare to other types of diesel vehicles. This reveals that most of the minibuses are of older model year and they are finding difficult to meet the emission standard.

- Vehicles of 20 year older in age are comparatively producing more smoke emission than vehicles of 20 year below in age.

- The repair of vehicles has significant reduction in smoke emission. The emission level was lower when the vehicles come for emission test after repair.

- The highest percentage of failure rate was observed for the group of vehicles belonging to the model year 1981-1990.

6. RECOMMENDATIONS

- Insertion of probe as per recommendation should be checked compulsorily prior to taking emission data.

- Recording of emission data from petrol vehicles should not be limited to CO and HC emissions only. CO_2, O_2 and Lambda (λ) should also be recorded, which will be helpful for data analysis.

- Revise existing emission standard for in-use vehicles. The existing two CO emission standards for petrol vehicle by model year can be merged to only one CO emission standard. Similarly, the existing two HSU (or k value) emission standards for diesel vehicles can be combined to one emission standard.

- Introduce separate emission standards for Euro-I vehicles and vehicles with catalytic converters.

- Tighten the emission standards (introduce stringent emission standard) in order to make Inspection and Maintenance Program more effective.

- Carry out road side emission test randomly for all kind of vehicles including two wheelers to get the real picture of the emissions produced by these vehicles.

- Work out on the scheme of replacing gross polluters.

- Carry out emission test on motor cycles.

- Introduce automatic system of testing emissions from the vehicles by recording the data in computer.

Appendix A: Nepal Vehicle Mass Emission Standard, 2056 (1999)

A. Vehicles Fueled with Gasoline (Positive Ignition Engines)

1 For Passenger Cars with Up To Six Seats and Gross Vehicle Weight (GVW) less than 2.5 tons

1.1 **Type 1 Test-** verifying exhaust emissions after a cold start.

	grams per kilometer	
	Carbon monoxide (CO)	Hydrocarbons plus oxides of nitrogen (HC + NOx)
Type Approval*	2.72	0.97
Conformity of Production**	3.16	1.13

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

1.2 **Type II Test-** carbon monoxide emission at idling speed.
This test applies to vehicles fueled with leaded gasoline only.
The carbon monoxide content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I test.

1.3 **Type III Test**- verifying emissions of crankcase gases.
The crankcase ventilation system must not permit the emission of any of the crankcase gases into the atmosphere.

1.4 **Type IV Test**- determination of evaporative emission
This test applies to all vehicles fueled with leaded and unleaded gasoline.
Evaporative emissions shall be less than 2g/test.

1.5 **Type V Test**- durability of pollution control devices.
This test applies to vehicles fueled with unleaded gasoline only.
The test represents and endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

2 For Light-Duty Commercial Vehicles and Vehicles with Gross Vehicle Weight (GVW) more than 2.5 tons

2.1 **Type 1 Test-** verifying exhaust emissions after a cold start.

Reference Mass (kg)		*grams per kilometer*	
		Carbon monoxide (CO)	Hydrocarbons plus oxides of nitrogen (HC + NOx)
RM<1250	Type Approval Conformity of production	2.27 3.16	0.97 1.13
1250<RM<1700	Type Approval Conformity of production	5.17 6.0	1.4 1.6
RM>1700	Type Approval Conformity of production	6.9 8.0	1.7 2.0

Note:

- *The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.*
- *Reference mass means the "unladen mass" (mass of the vehicle in running order without crew, passengers or load, but with the fuel tank full and the usual set of tools and spare wheel on board, when applicable) of the vehicle increased by an uniform figure of 100 kg.*
- *Includes passenger vehicles with seating capacity more than six persons or reference mass more than 2,500 kg.*

2.2 **Type II Test-** carbon monoxide emission at idling speed.
This test applies to vehicles fueled with leaded gasoline only.
The carbon monoxide content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I Test.

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Evaporative emissions shall be less than 2g/test.

2.5 **Type V Test**- durability of pollution control devices.
This test applies to vehicles fueled with unleaded gasoline only.
The test represents and endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

3 For Two Wheelers and Three Wheelers

3.1 **Type 1 Test-** verifying exhaust emissions after a cold start.

	CO (grams per kilometer)		HC + NOx (grams per kilometer)	
	2-Wheeler	3-Wheeler	2-Wheeler	3-Wheeler
Type Approval	2.0	4.0	2.0	2.0
Conformity of Production	2.4	4.8	2.4	2.4

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

3.2 **Type II Test-** carbon monoxide emission at idling speed.
This test applies to vehicles fueled with leaded gasoline only.
The carbon monoxide content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I Test.

3.3 **Type III Test-** verifying emissions of crankcase gases.
The crankcase ventilation system must no permit the emission of any of the crankcase gases into the atmosphere.

3.4 **Type IV Test-** determination of evaporative emission.
This test applies to all vehicles fueled with leaded and unleaded gasoline.
Evaporative emissions shall be less than 2g/test.

3.5 **Type V Test**- durability of pollution control devices.
This test applies to vehicles fueled with unleaded gasoline only.
The test represents and endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

B. Vehicles Fueled with Diesel (Compression ignition engines)

1. Passenger Cars with up to Six Seats and Gross Vehicle Weight (GVW) less than 2.5 tons

1.1 **Type 1 Test-** verifying exhaust emissions after a cold start.

	grams per kilometer		
	CO	HC + NOx	PM (Particulate Matter)
Type Approval	2.72	0.97	0.14
Conformity of Production	3.16	1.13	0.18

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

1.2 **Type II Test-** carbon monoxide emission at idling speed.
*Not applicable***.**

1.3 **Type III Test-** verifying emissions of crankcase gases.
The crankcase ventilation system must no permit the emission of any of the crankcase gases into the atmosphere.

1.4 **Type IV Test-** determination of evaporative emission.
Not applicable.

1.5 **Type V Test**- durability of pollution control devices.
The test represents and endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

2 **For Light-Duty Commercial Vehicles and Vehicles with Gross Vehicle Weight (GVW) more than 2.5 tons.**

2.1 **Type 1 Test-** verifying exhaust emissions after a cold start.

Reference Mass (kg)		grams per kilometer		
		CO	HC + NOx	PM
RM<1250	Type Approval Conformity of production	2.72 3.16	0.97 1.13	0.14 0.18
1250<RM<1700	Type Approval Conformity of production	5.17 6.0	1.4 1.6	0.19 0.22
RM>1700	Type Approval Conformity of production	6.9 8.0	1.7 2.0	0.25 0.29

Note: The test shall be as per the Driving Cycle adopted by different countries, with cold start on Chassis Dynamometer.

- *Reference mass means the “unladen mass” (mass of the vehicle in running order without crew, passengers or load, but with the fuel tank full and the usual set of tools and spare wheel on board, when applicable) of the vehicle increased by an uniform figure of 100 kg.*
- *Includes passenger vehicles with seating capacity more than six persons or reference mass more than 2,500 kg.*

2.2 **Type II Test-** carbon monoxide emission at idling speed.
*Not applicable***.**

2.3 **Type III Test-** verifying emissions of crankcase gases.
The crankcase ventilation system must no permit the emission of any of the crankcase gases into the atmosphere.

2.4 **Type IV Test-** determination of evaporative emission.
Not applicable.

2.5 **Type V Test**- durability of pollution control devices.

The test represents and endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

3 For Heavy-Duty Vehicles and Vehicles with Gross Vehicle Weight (GVW) more than 3.5 tons

3.1 **Type 1 Test-** verifying exhaust emissions after a cold start.

Pollutants	Type Approval	Conformity of Production
CO (grams per kilo-watt hour)	4.5	4.9
HC (grams per kilo-watt hour)	1.10	1.23
NOx (grams per kilo-watt hour)	8.0	9.0
PM (grams per kilo-watt hour) for engines with power less than 85 kW	0.61	0.68
PM (grams per kilo-watt hour) for engines with power more than 85 kW	0.36	0.40

Note: The test shall be as per the Driving Cycle adopted by different countries with 13 Mode Emissions Engines Dynamometer Test.

3.2 **Type II Test-** carbon monoxide emission at idling speed.
*Not applicable***.**

3.3 **Type III Test-** verifying emissions of crankcase gases.
The crankcase ventilation system must no permit the emission of any of the crankcase gases into the atmosphere.

3.4 **Type IV Test-** determination of evaporative emission.
Not applicable.

3.5 **Type V Test**- durability of pollution control devices.
The test represents and endurance test of 80,000 kilometer driven on the road or on a chassis dynamometer.

Explanatory Notes

1.0 Type Approval

Most countries require some form of certification or type approval by vehicle manufacturer to demonstrate that each new vehicle sold is capable of meeting applicable emission standards. Usually, type approval requires emission testing of prototype vehicles representative of planned production vehicles. Under ECE and Japanese regulations, such compliance is required only for new vehicles. U.S. regulations require that vehicles comply with emission standards throughout their useful lives when maintained accordingly to the manufacturing specifications.

The advantage of the certificate or type approval program is that it can influence vehicle design prior to mass production. It is more cost effective because the manufacturers identify and correct the problems before production actually begins.

2.0 Approval of a Vehicle

Vehicle manufacturers apply for approval of a vehicle type with regard to exhaust emissions, evaporative emissions and durability of pollution control devices to the authority responsible for conducting tests. The application for approval also includes details like description of engines type comprising of all the particulars, drawings of the combustion chamber and of the piston, description of evaporative control system, particulars concerning the vehicles, descriptions of pollution control devices etc. If the vehicle type submitted for approval meets the requirements of various types of tests mentioned, only then the approval of that vehicle is granted.

3.0 Conformity of Production

The conformity of production is an assembly line testing system. The objectives of assembly line testing are to enable regulatory authorities to identify certified production vehicles that do not comply with applicable emission standards, to take remedial actions (such as revoking certification and recalling vehicles) to correct the problem, and to discourage the manufacture of non-complying vehicles. This test provides an additional check on mass-produced vehicles to assure that the designs found adequate in certification are satisfactorily translated into production, and that quality control on the assembly line is sufficient to provide reasonable assurance that vehicles in use meet standards. The basic difference between TA and COP is that TA is based on prototype vehicle or design of a vehicle while COP measures emissions from real production vehicles.

As per the requirements set forth by the European Union, a sufficient number of random checks are made of serially-manufactured vehicles bearing the type approval mark of vehicles bearing all the types of tests mentioned above. The tolerance limits are provided for conformity of production in Type I tests.

Reference:

1. "Nepal Vehicle Mass Emission Standard, 2056", 2056 Paush 11[Decmeber 26, 1999], Gorkhapatra.

Appendix B: Cumulative distribution of emissions from three-wheelers

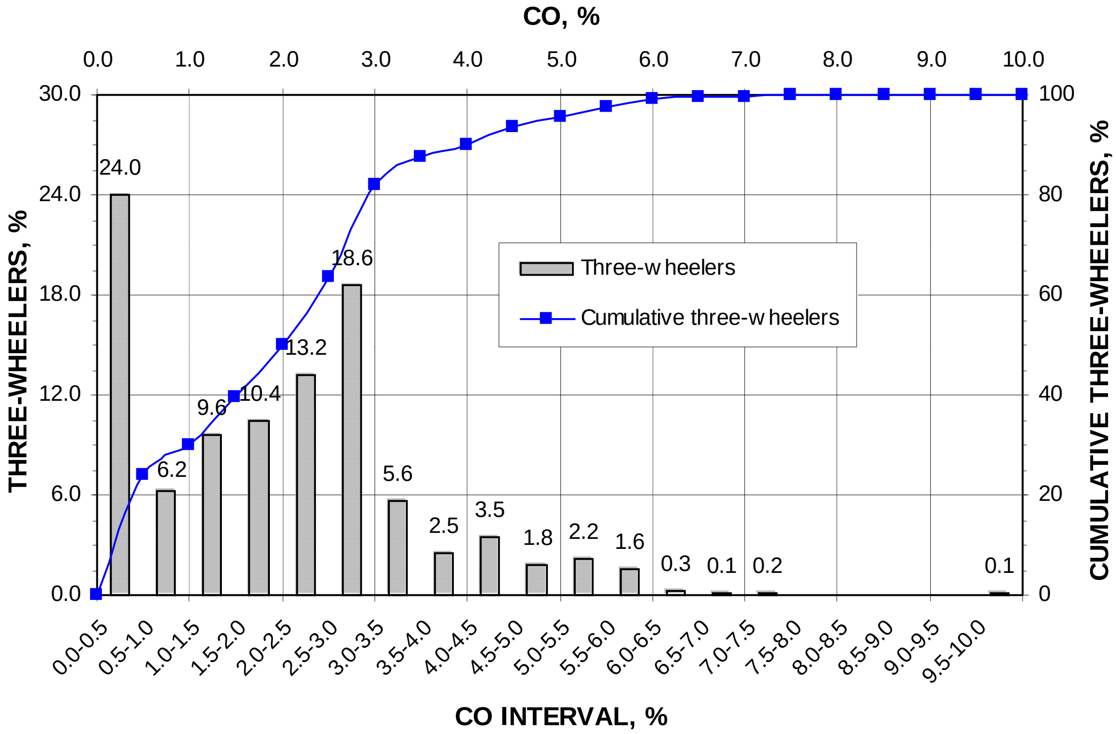

Figure B-1 CO distribution for three-wheelers in 2057-58

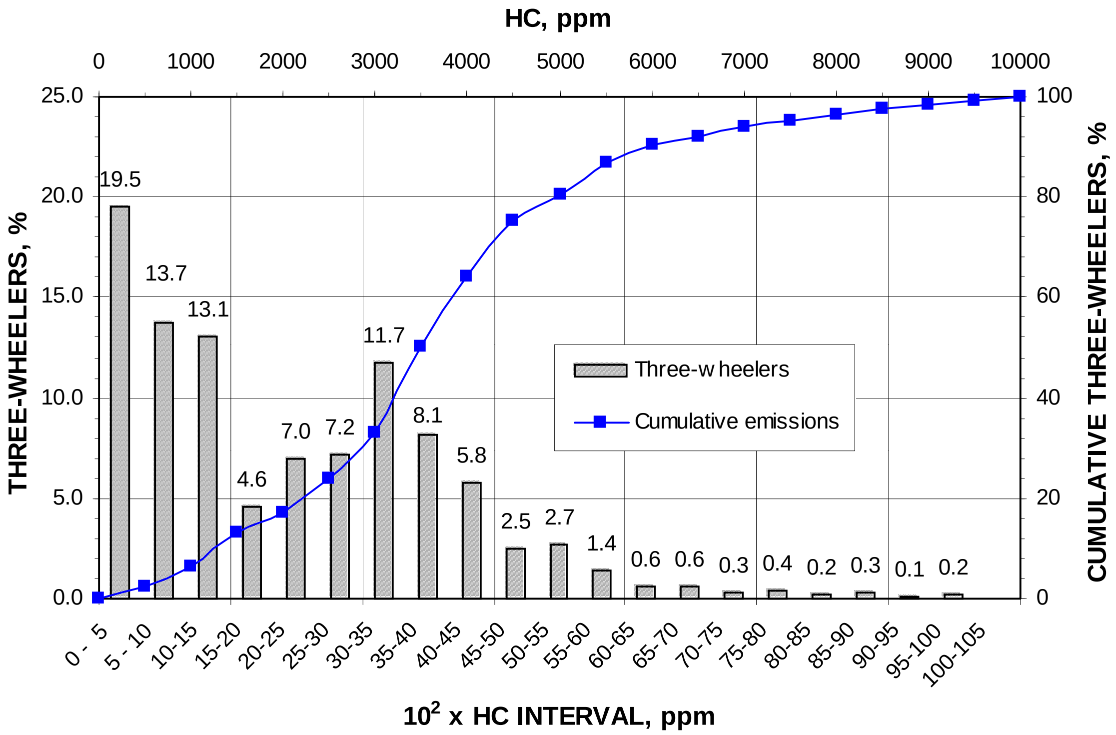

Figure B-2 HC distribution from three-wheelers in 2057-58

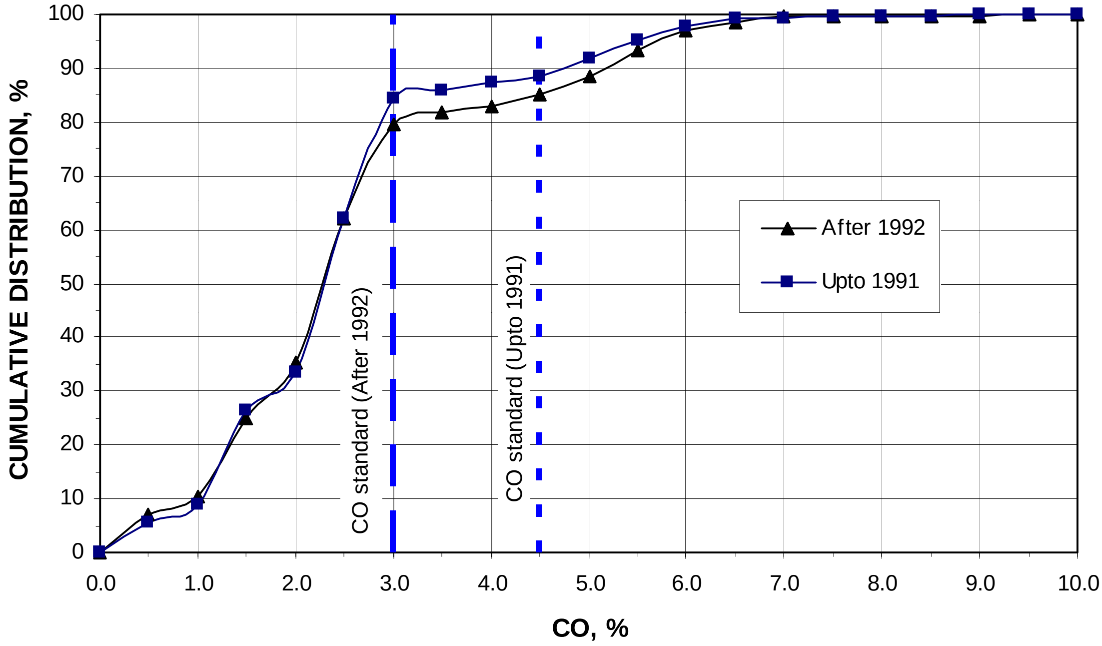

Figure B-3 CO distribution from three-wheelers by model year up to 1991 and after 1992 in 2058-59

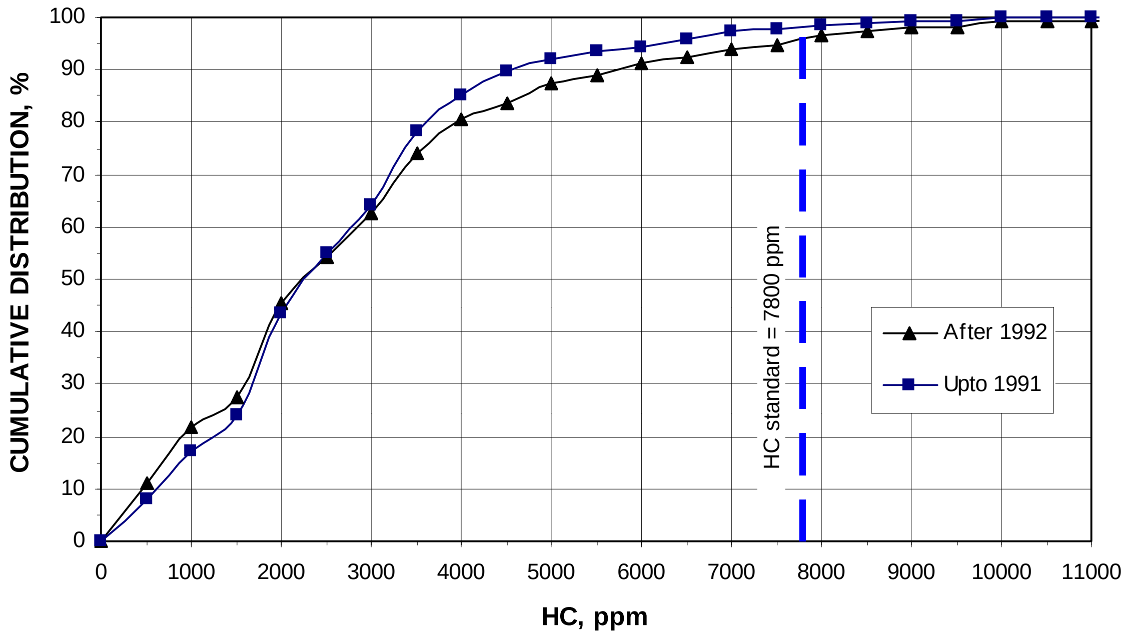

Figure B-4 HC distribution from three-wheelers by model year up to 1991 and after 1991 in 2058-59

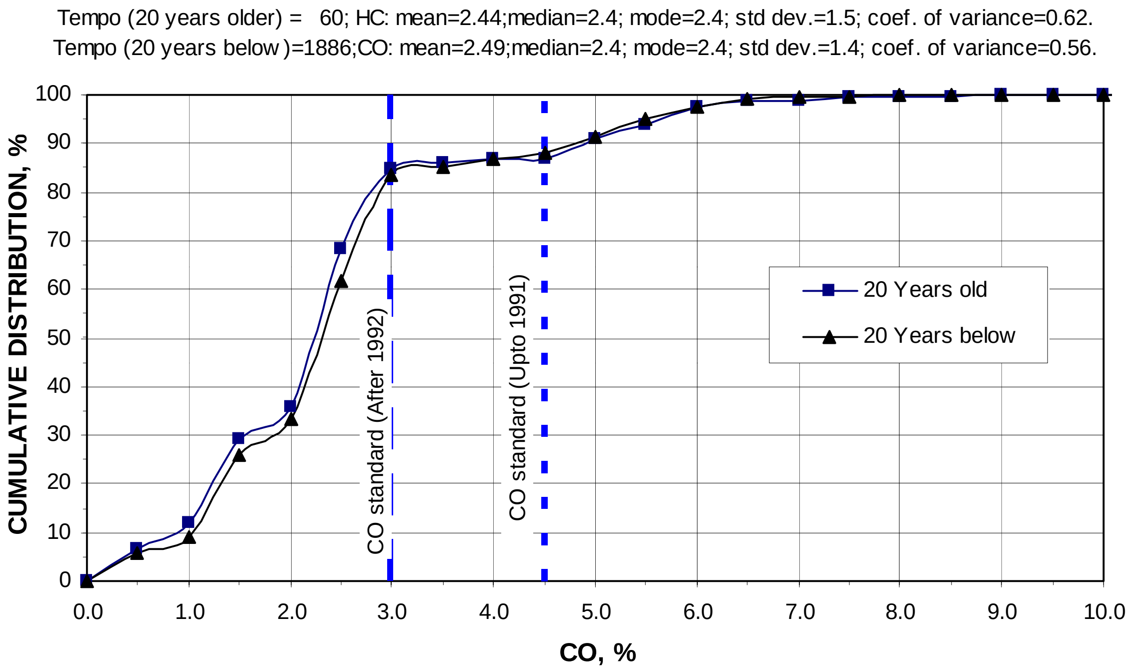

Figure B-5 CO distribution from three-wheelers by age in 2058-59

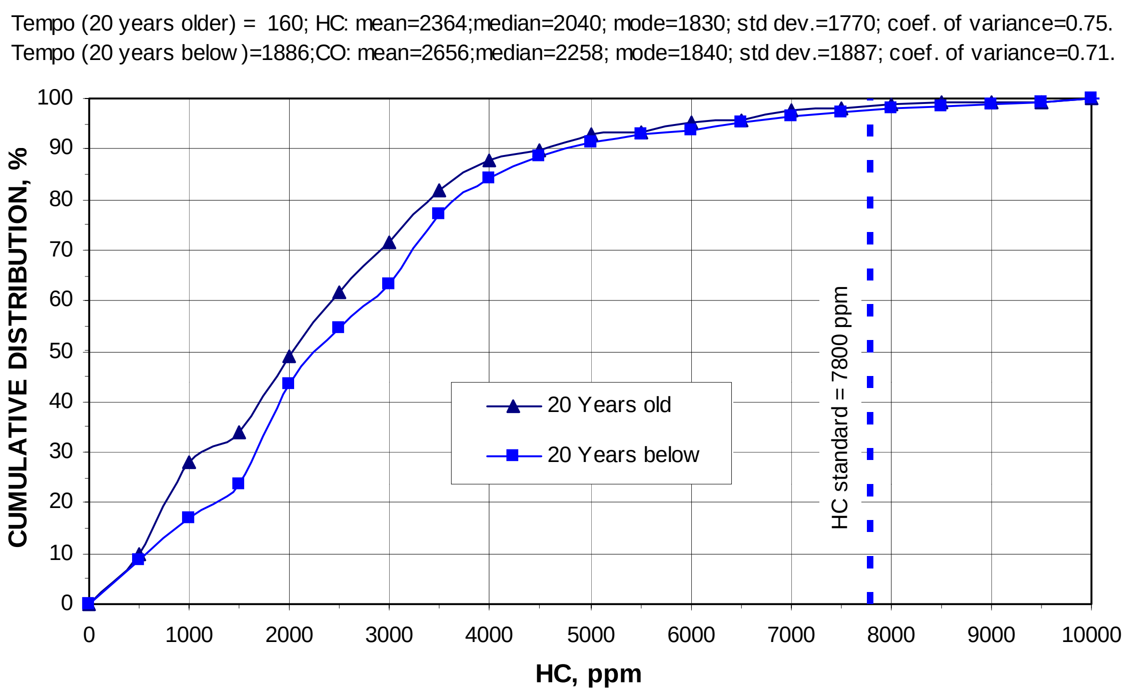

Figure B-6 HC distribution from three-wheelers by age in 2058-59

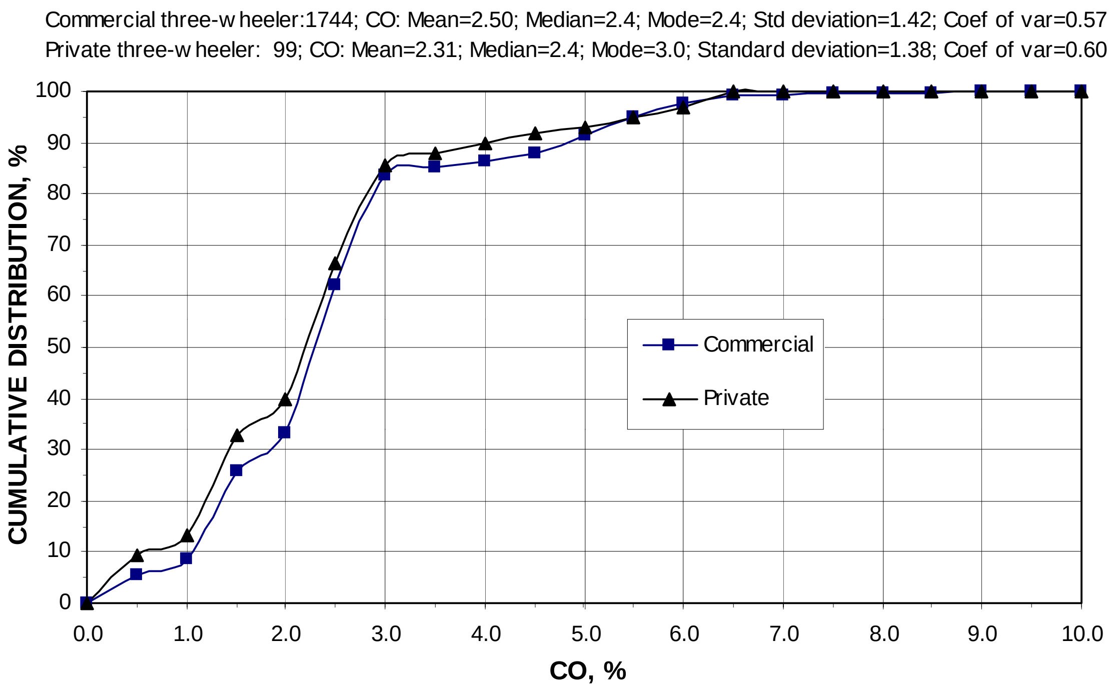

Figure B-7 CO distribution from three-wheelers category in 2058-59

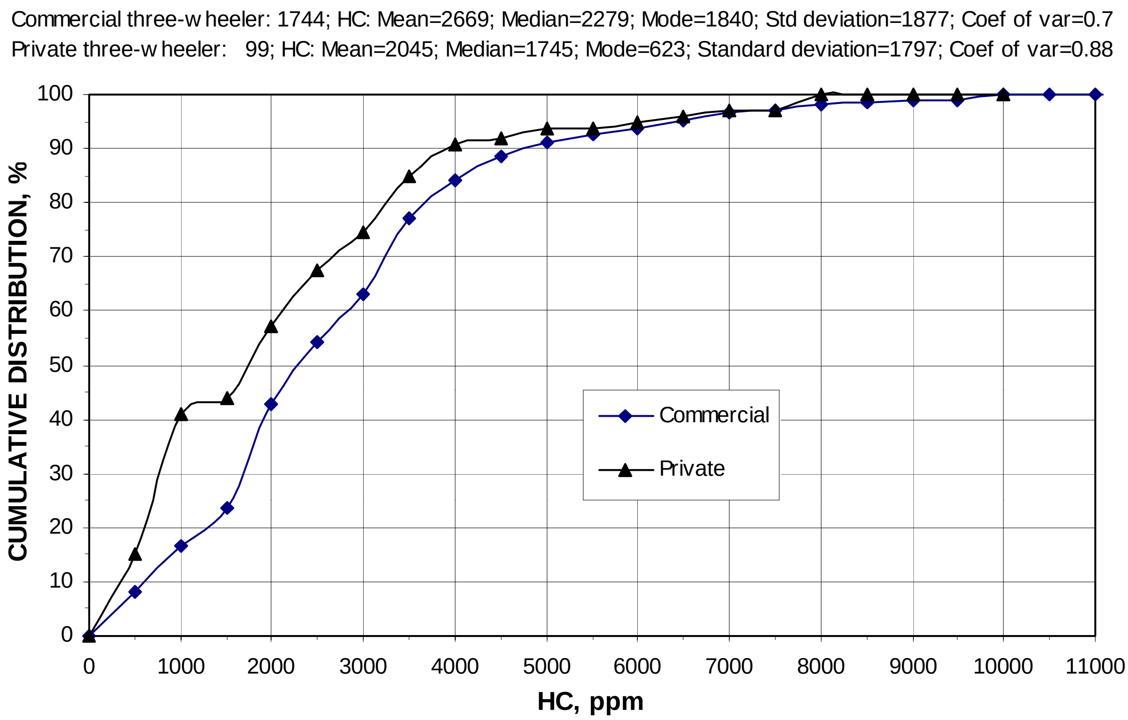

Figure B-8 HC distribution from three-wheelers by category in 2058-59

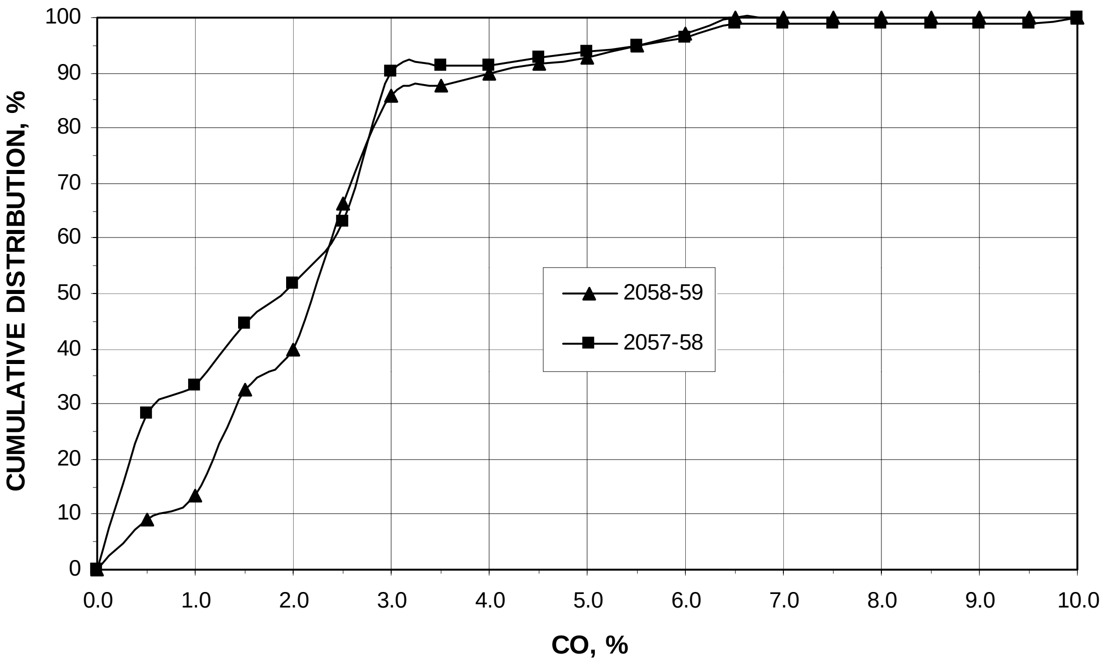

Figure B-9 CO distribution from private three-wheelers in 2057-58 and 2058-59

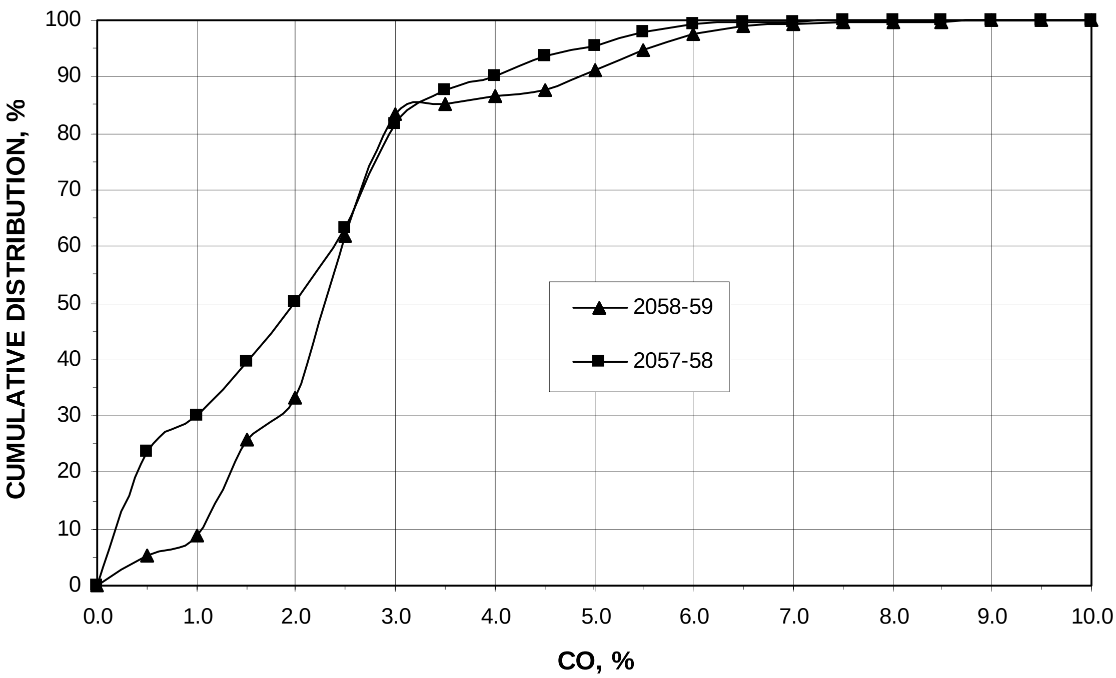

Figure B-10 CO distribution from commercial three-wheelers in 2057-58 and 2058-59

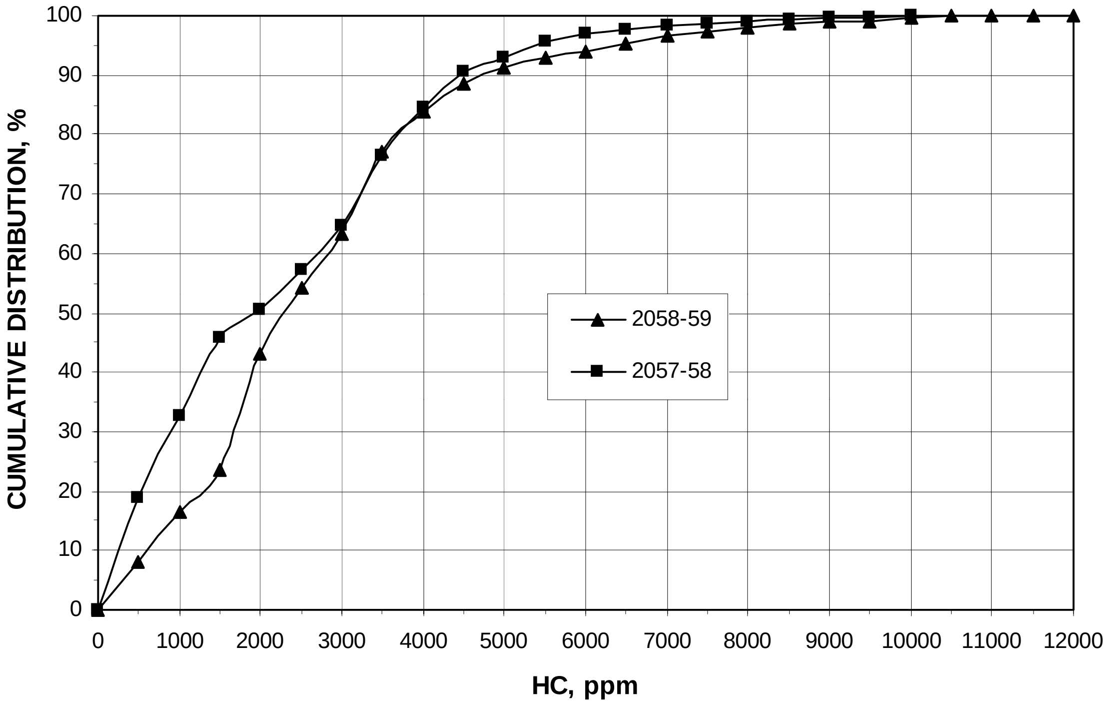

Figure B-11 HC distribution from commercial three-wheelers in 2057-58 and 2058-59

Appendix C: Cumulative distribution of emissions from car, jeep and van.

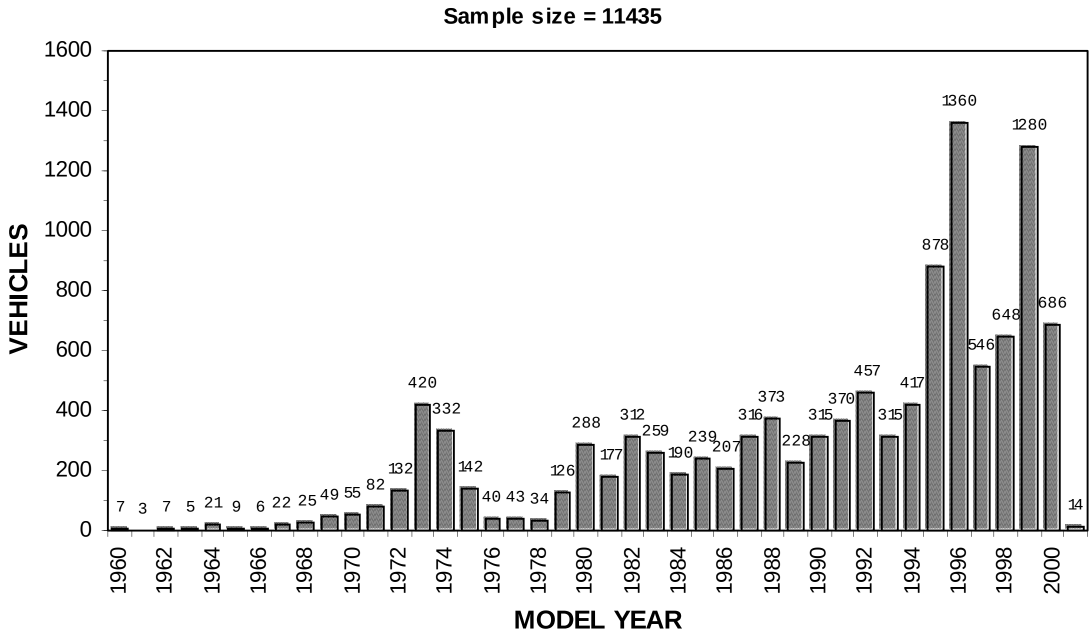

Figure C-1 Petrol vehicles (four wheelers) undergone emission test in 2057/58

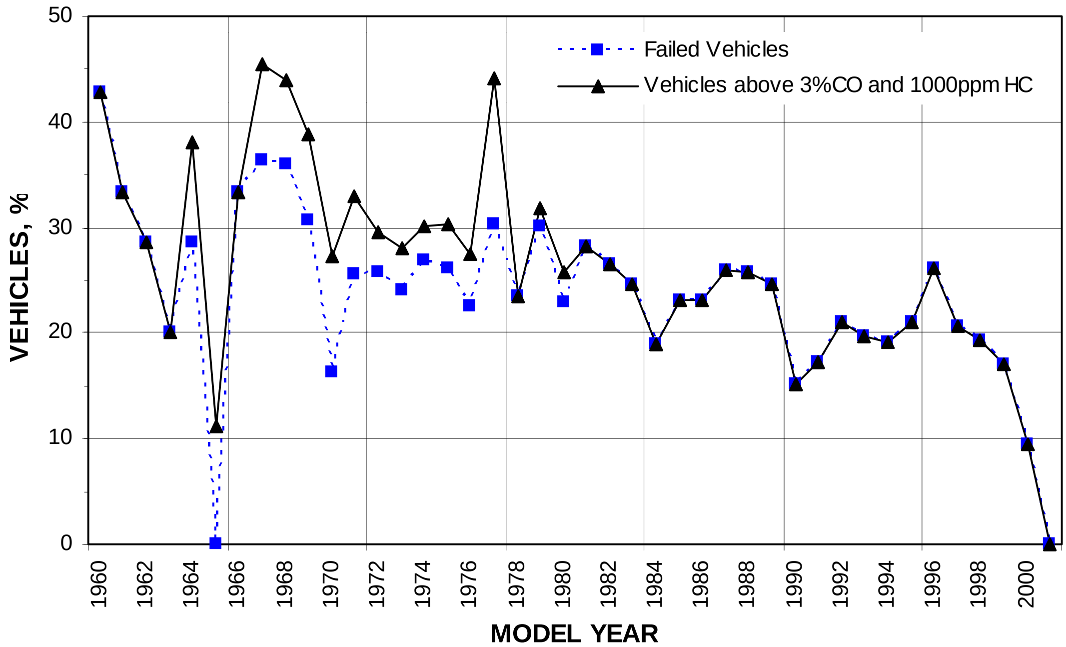

Figure C-2 Percentage of failed vehicles and vehicles exceeding emission standard (3% CO and 1000 ppm HC) in 2057/58

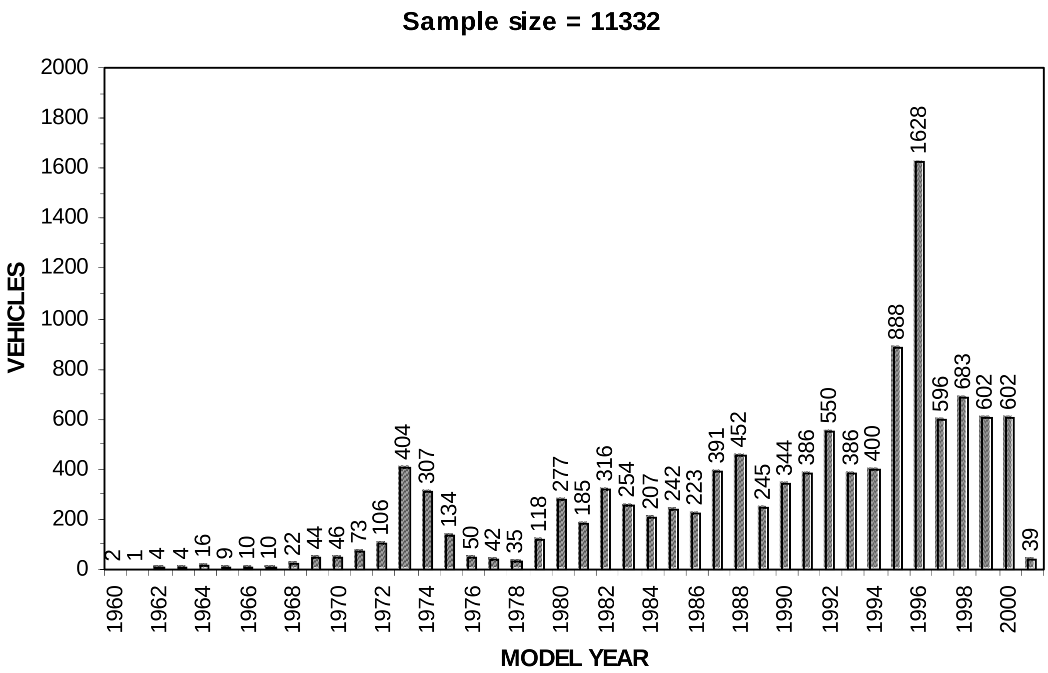

Figure C-3 Petrol vehicles (four wheelers) undergone emission test in 2058/59

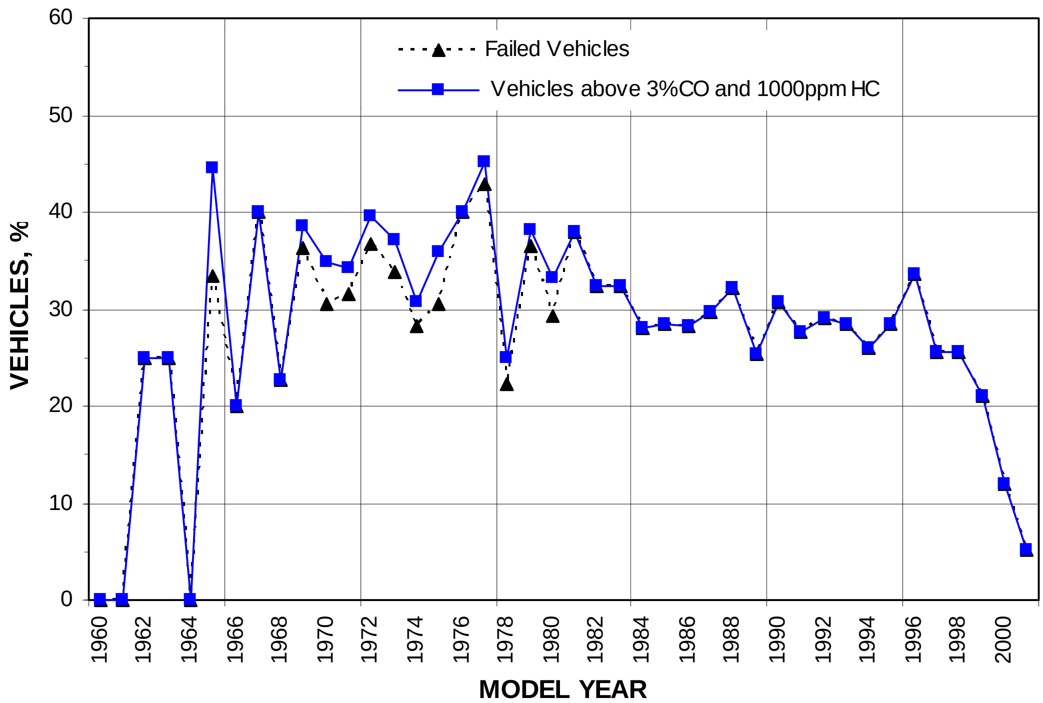

Figure C-4 Percentage of failed vehicles and vehicles above emission standard (3% CO and 1000 ppm HC) in 2058/59

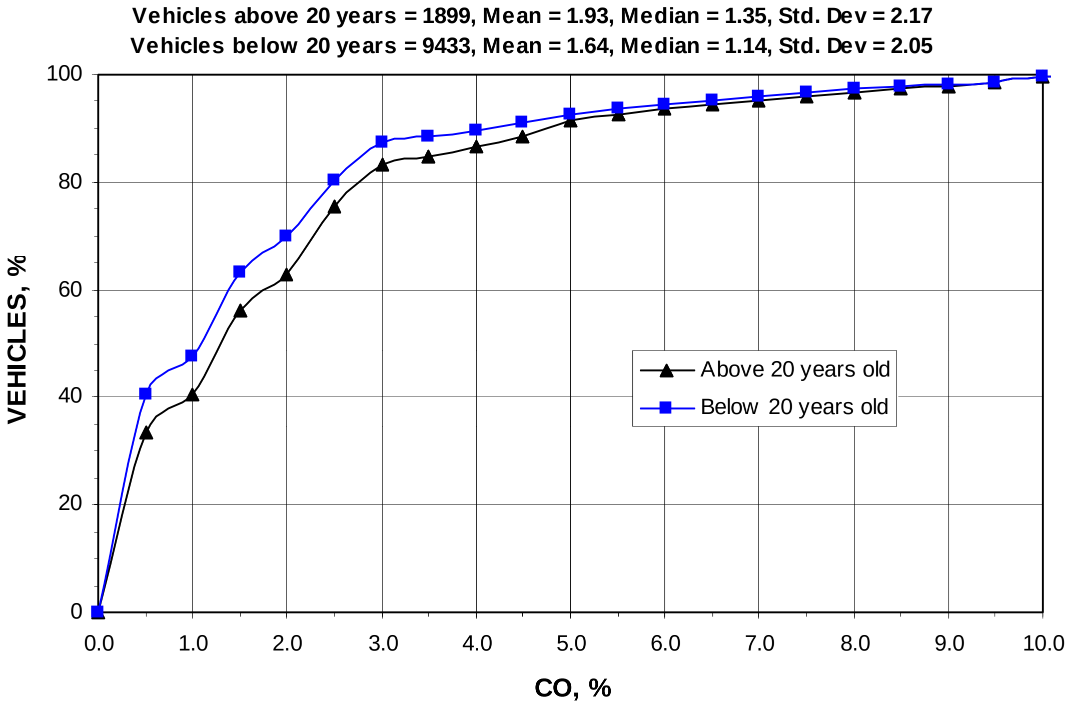

Figure C-5 CO distribution from petrol four wheelers by age in 2058/59

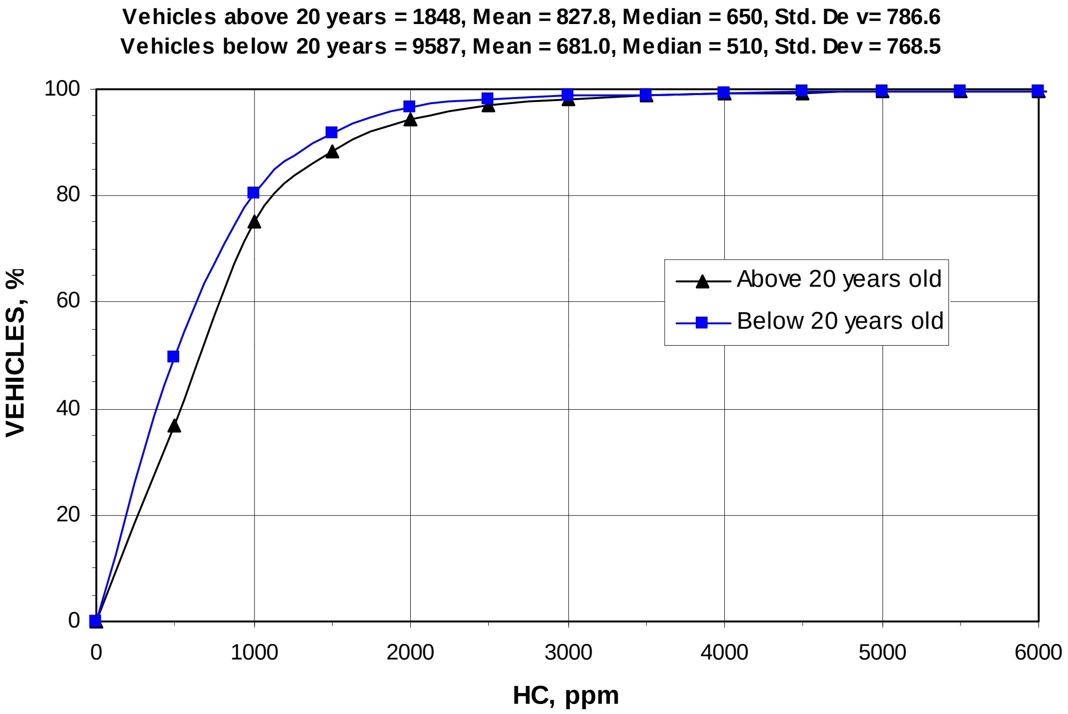

Figure C-6 HC distribution from petrol four wheelers by age in 2058/59

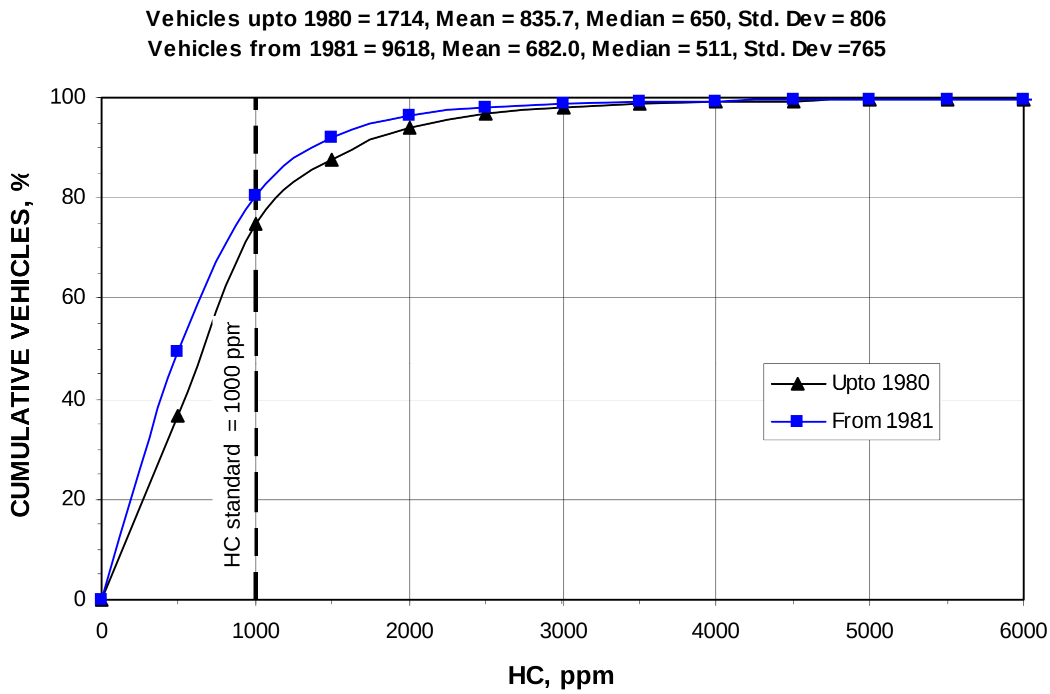

Figure C-7 HC distribution from petrol four wheelers by model in 2058/59

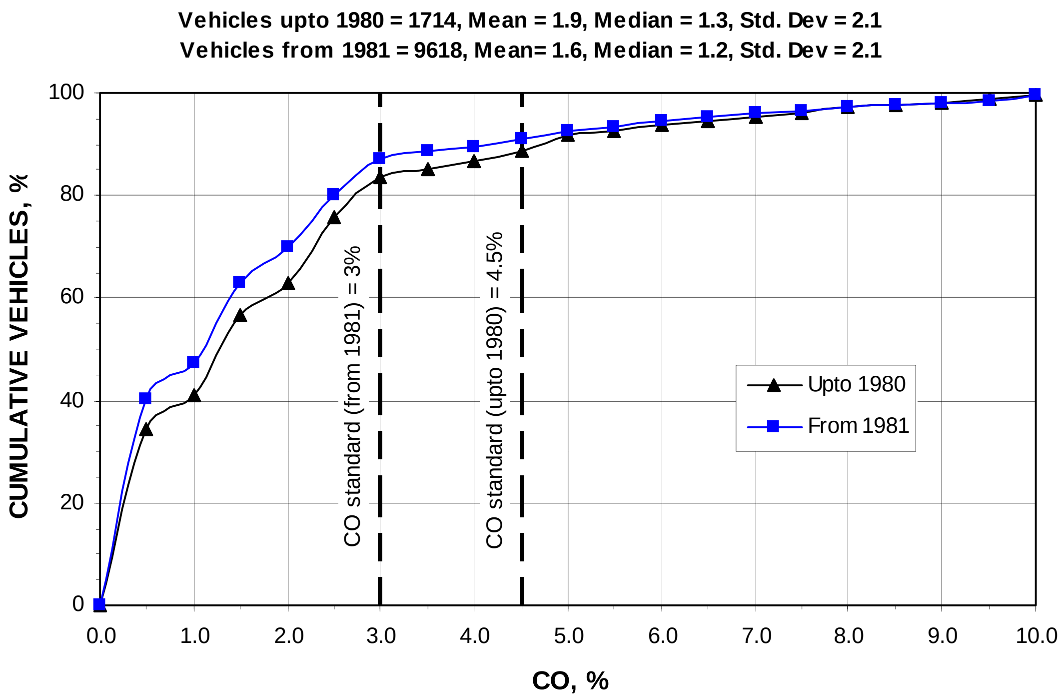

Figure C-8 CO distribution from petrol four wheelers by model year group in 2058/59

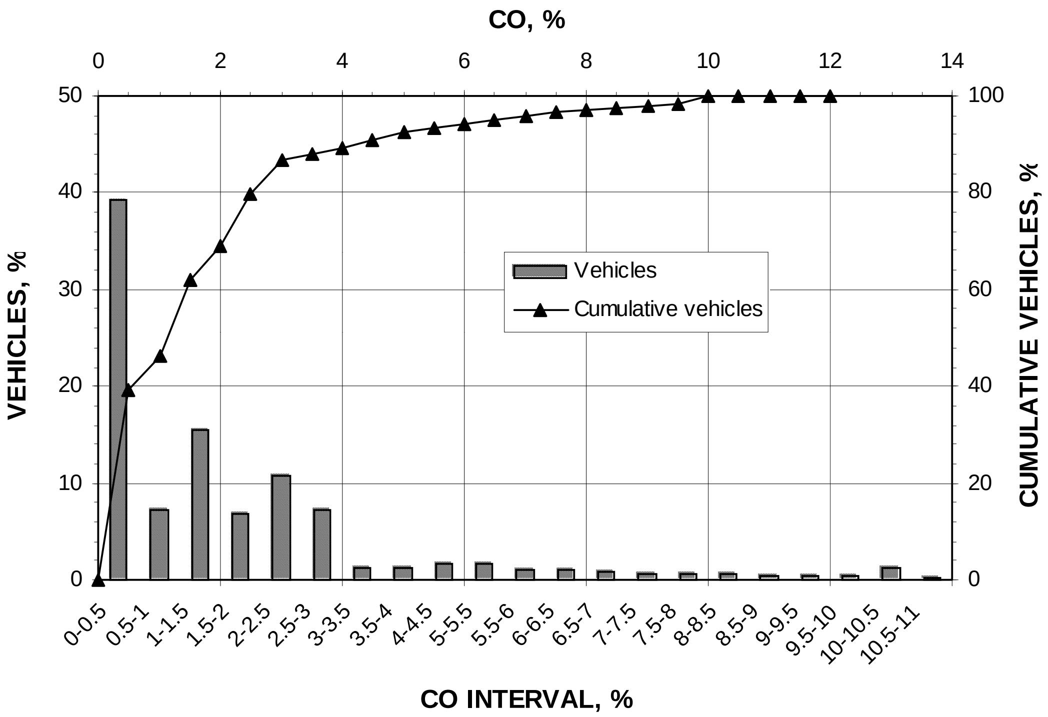

Figure C-9 CO distribution from four wheelers in 2058/59

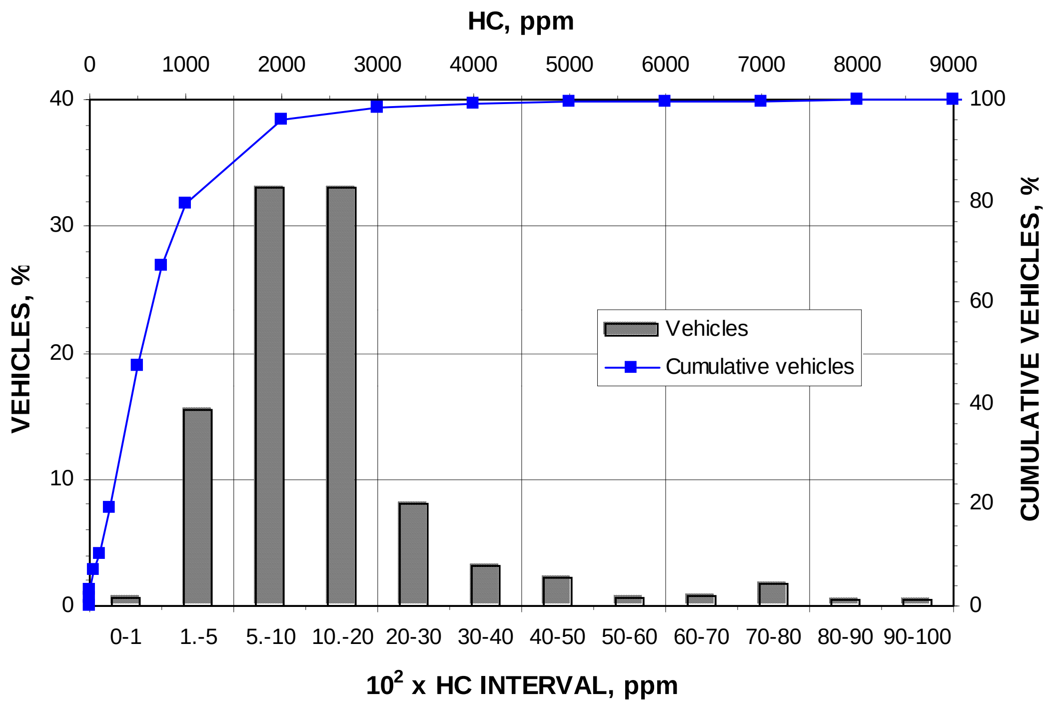

Figure C-10 HC distribution from four wheelers in 2058/59

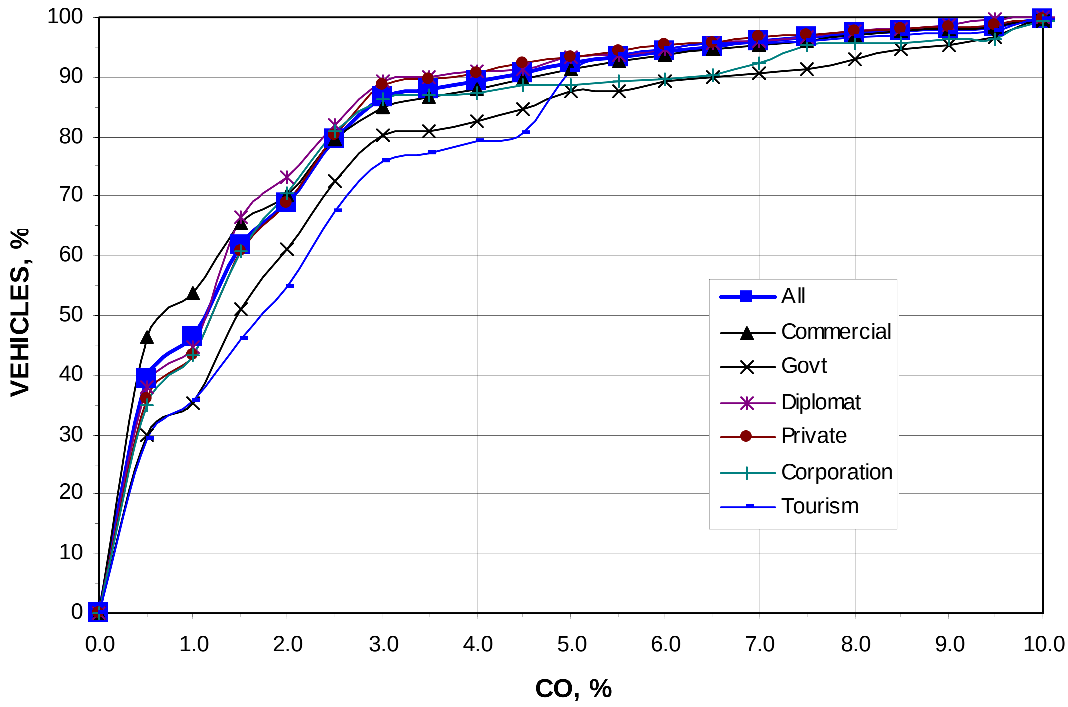

Figure C-11 CO distribution from petrol four wheelers by category in 2058/59

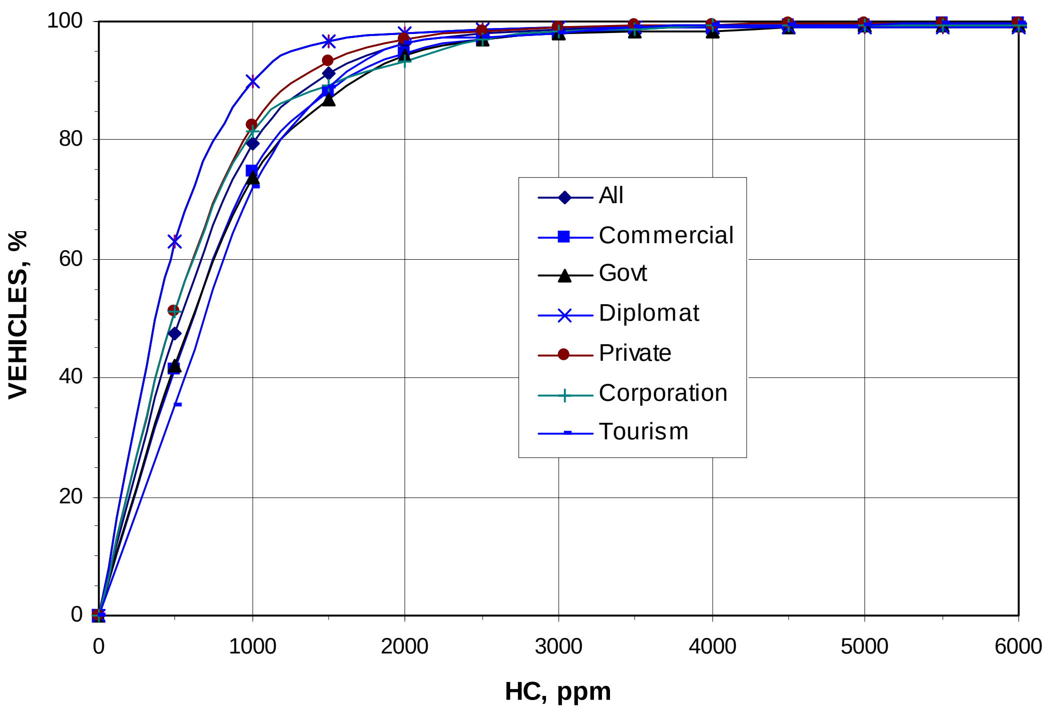

Figure C-12 HC distribution from petrol four wheelers by category in 2058/59

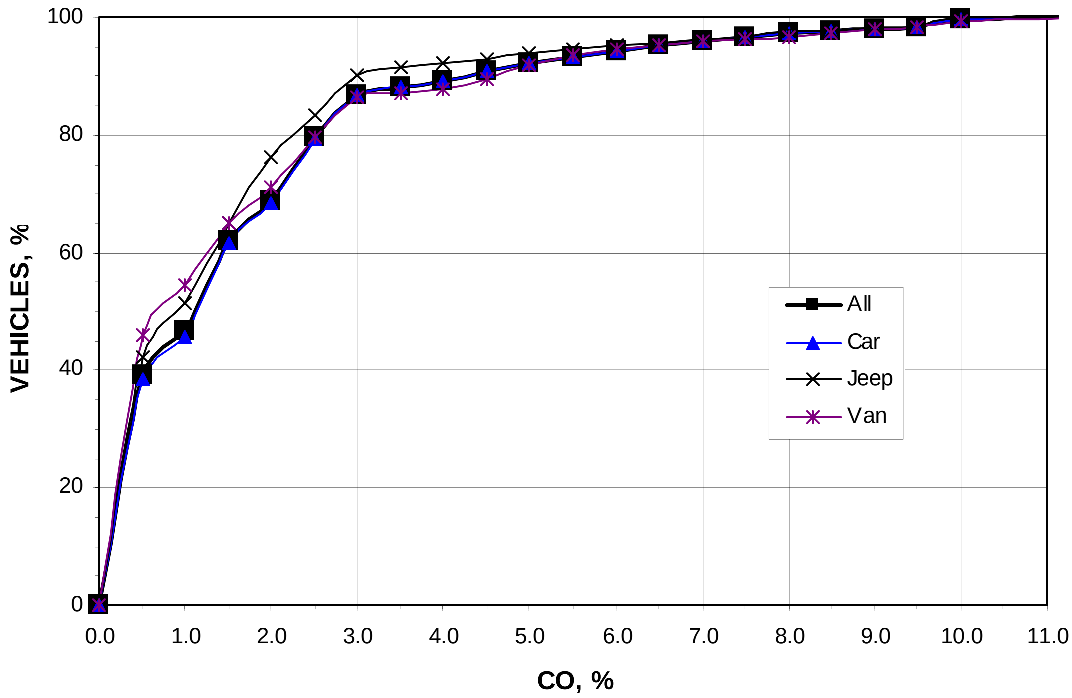

Figure C-13 CO distribution from petrol four wheelers by type in 2058/59

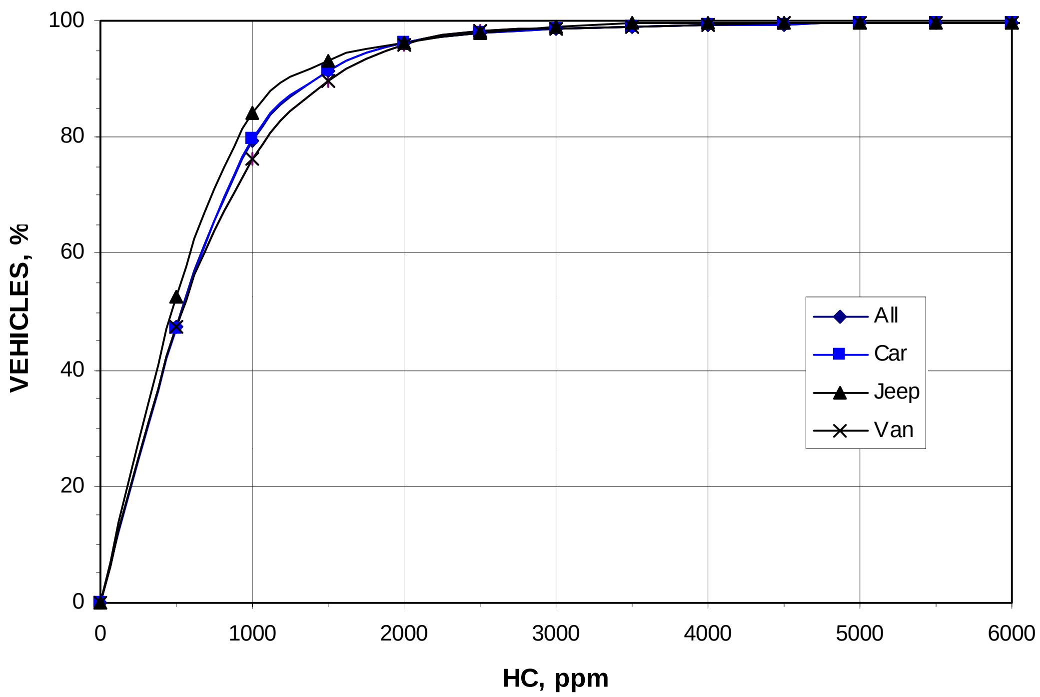

Figure C-14 HC distribution from petrol four wheelers by type in 2058/59

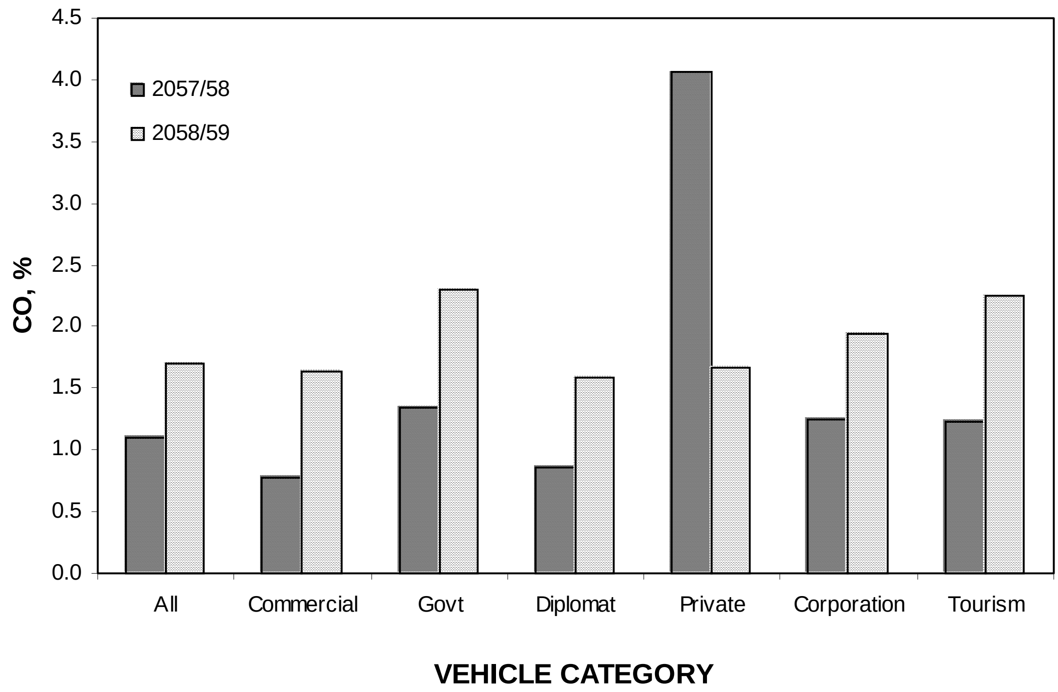

Figure C-15 Average CO from petrol four wheelers by category

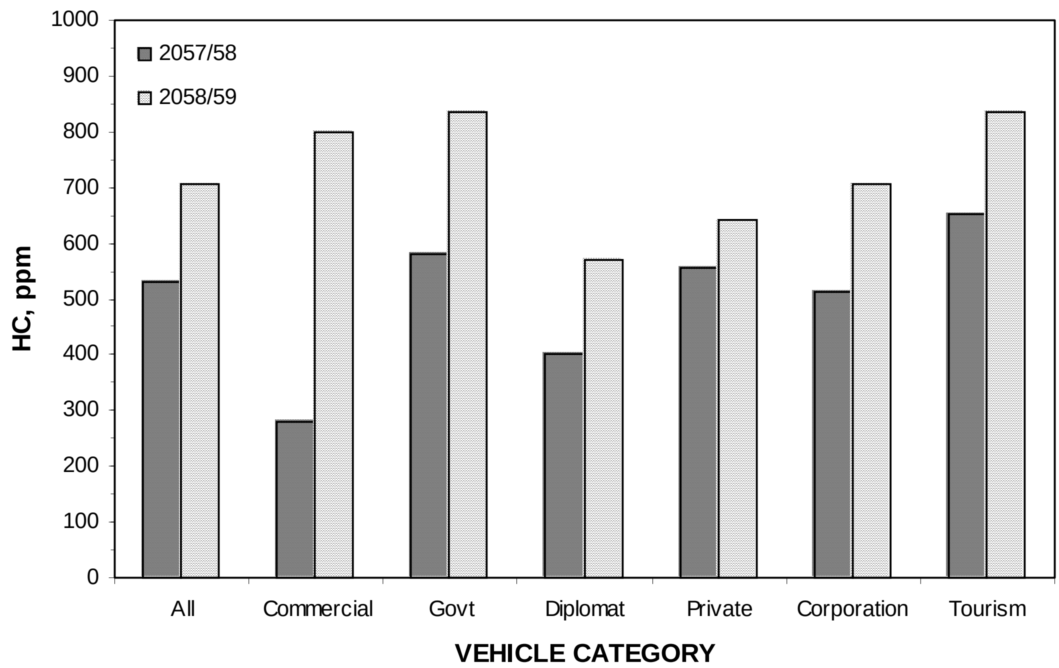

Figure C-16 Average HC from the petrol four wheelers by category

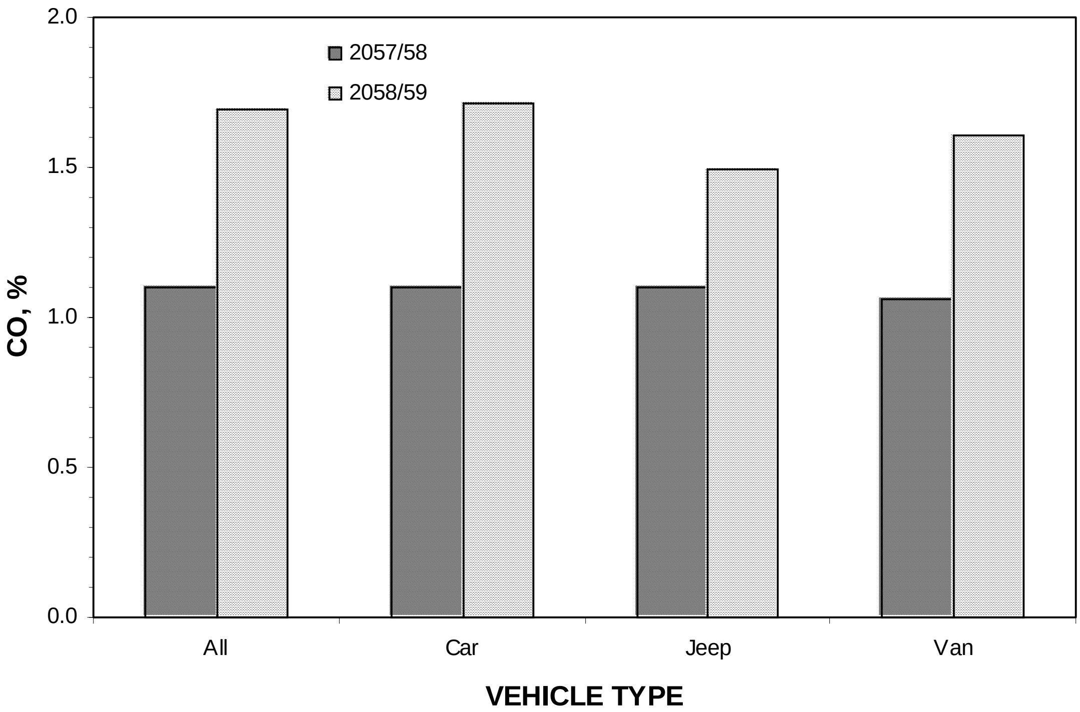

Figure C-17 Average CO from the petrol four wheelers by type

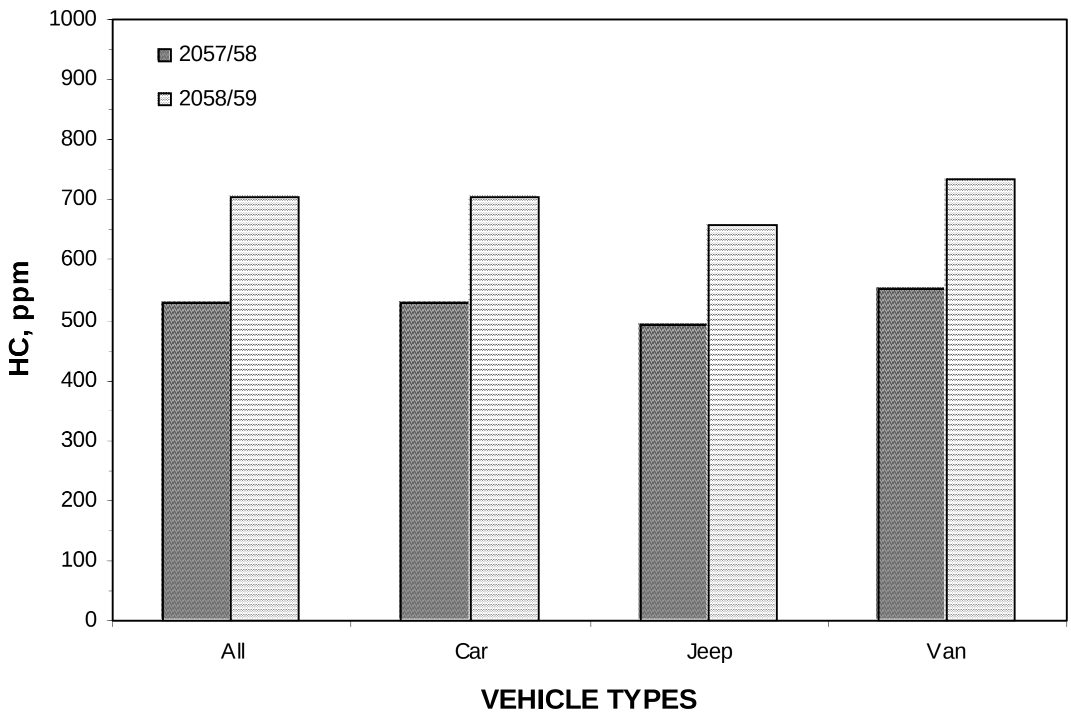

Figure C-18 Average HC from the petrol four wheelers by type

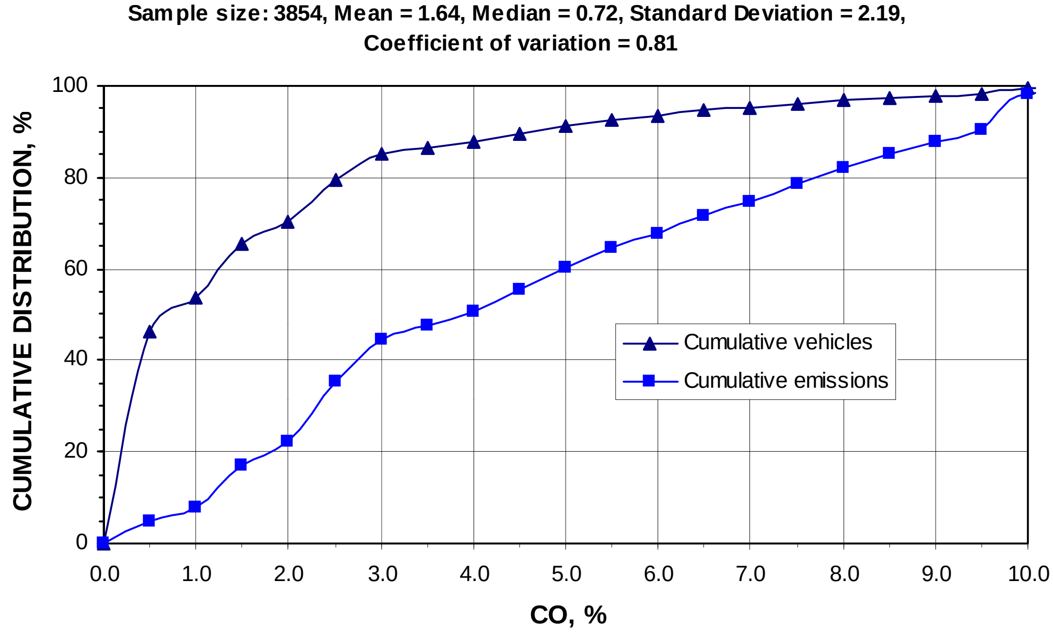

Figure C-19 CO distribution from commercial petrol four wheelers in 2058/59

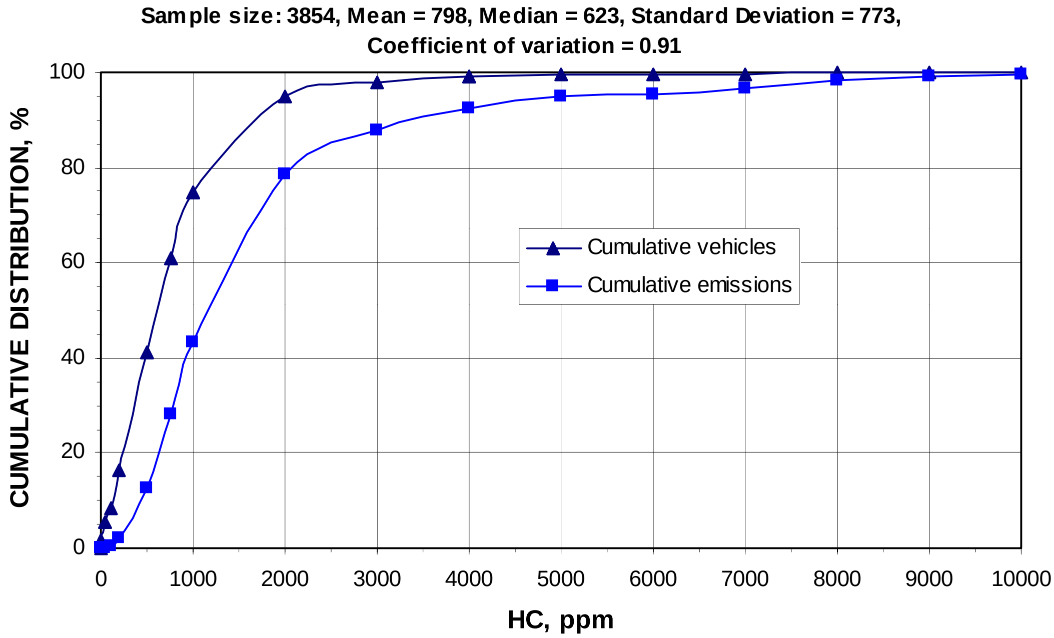

Figure C-20 HC distribution from commercial petrol four wheelers in 2058/59

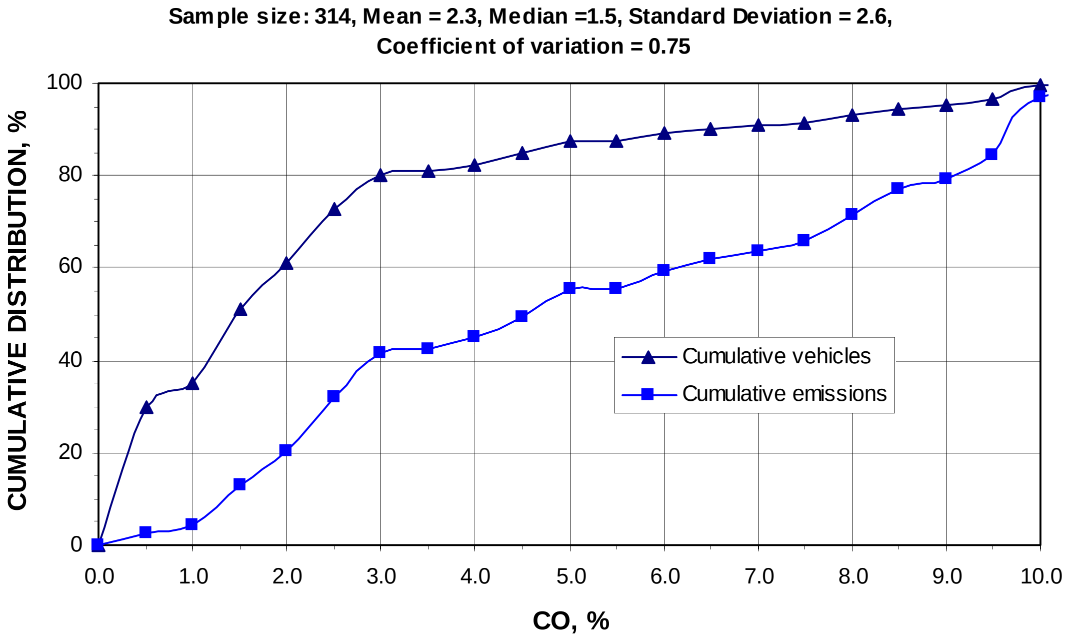

Figure C-21 CO distribution from government petrol four wheelers in 2058/59

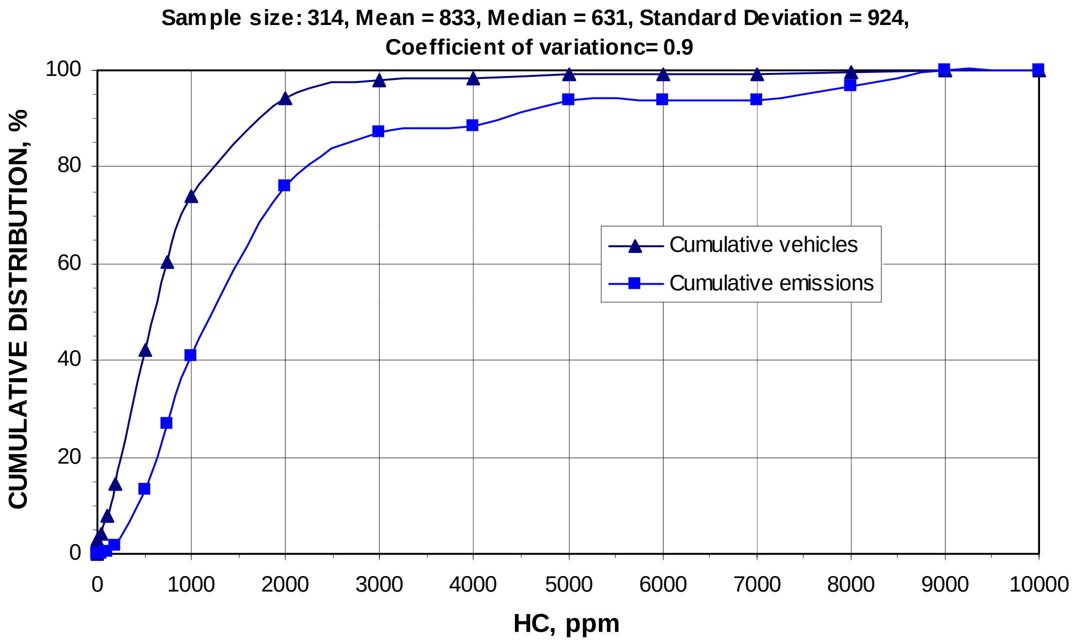

Figure C-22 HC distribution from government petrol four wheelers in 2058/59

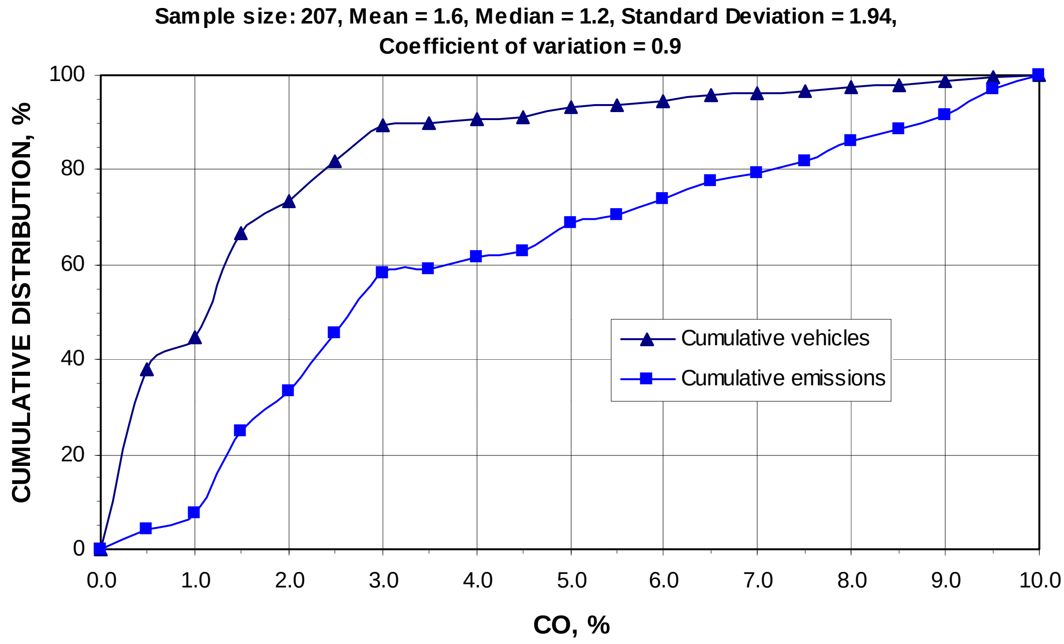

Figure C-23 CO distribution from diplomatic petrol four wheelers in 2058/59

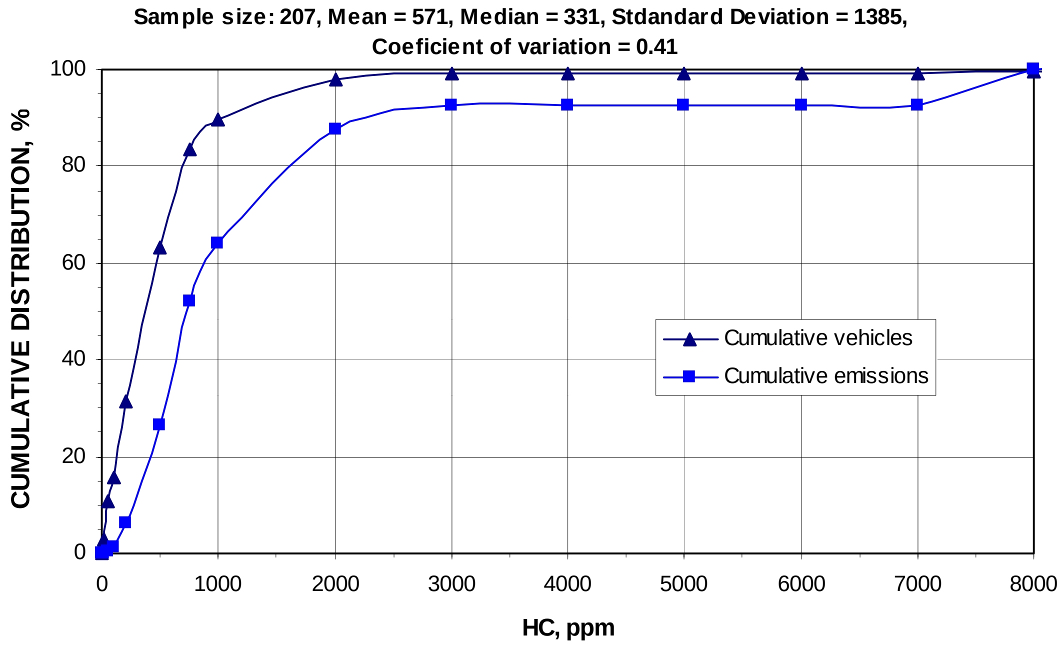

Figure C-24 HC distribution from diplomatic petrol four wheelers in 2058/59

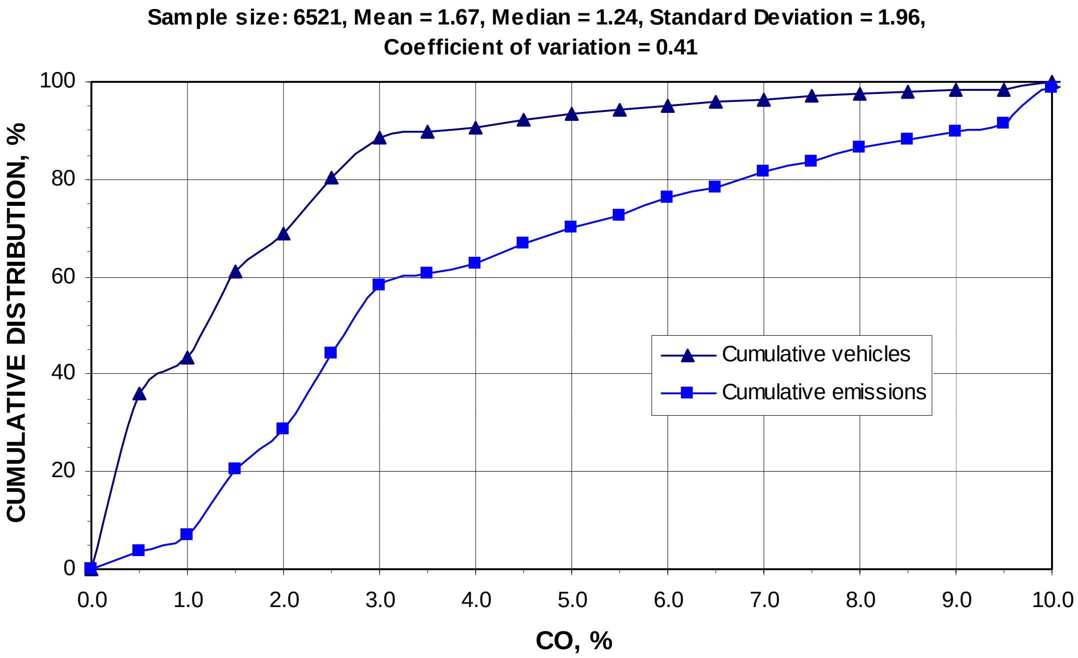

Figure C-25 CO distribution from private petrol four wheelers in 2058/59

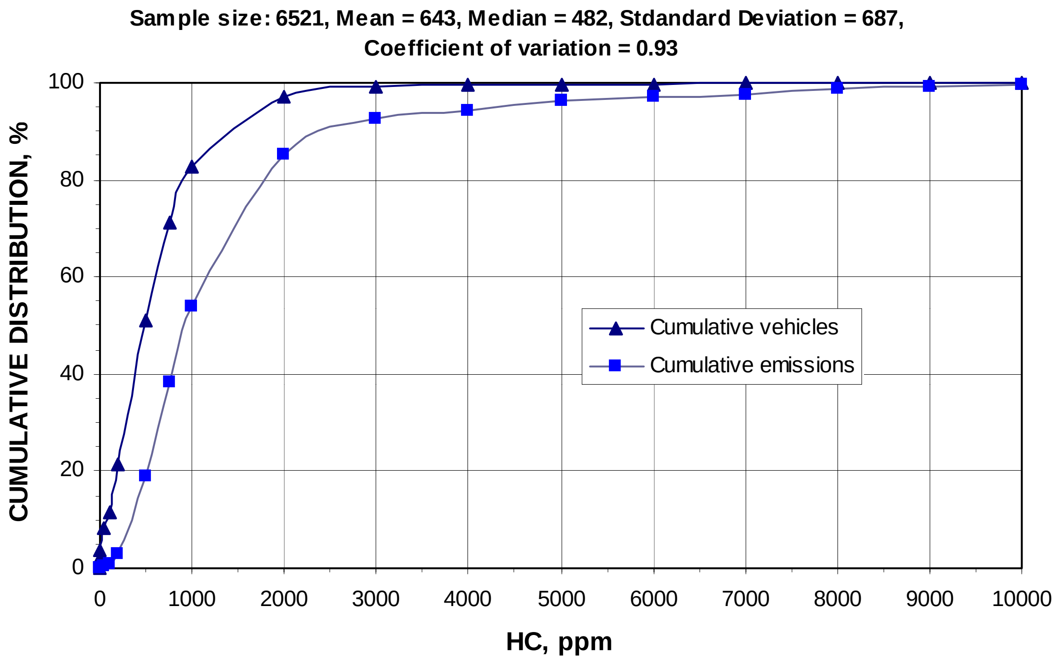

Figure C-26 HC distribution from private petrol four wheelers in 2058/59

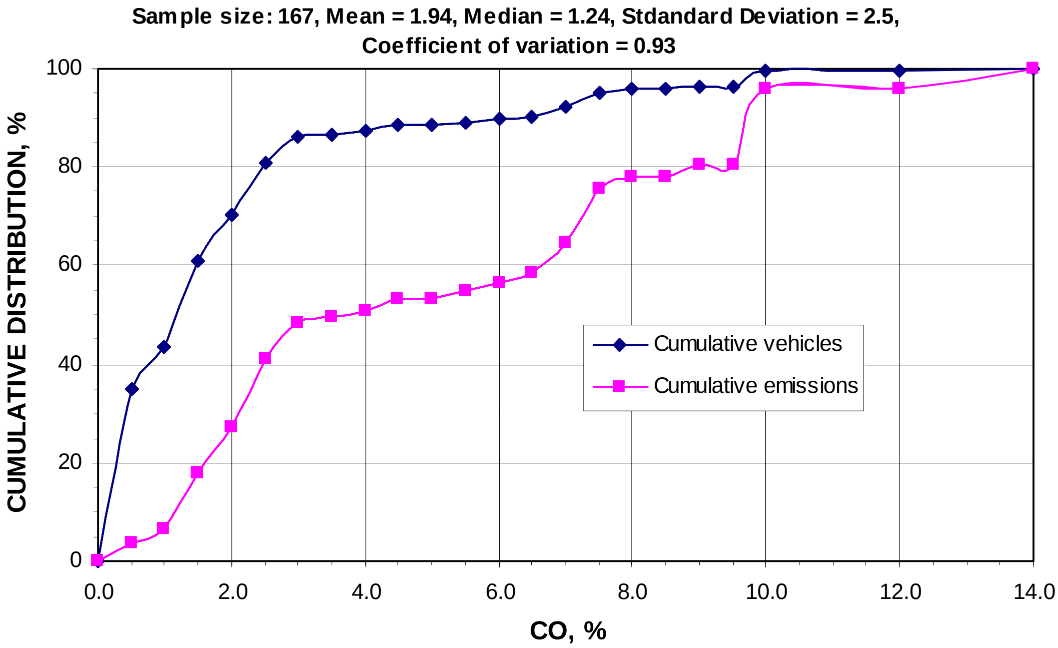

Figure C-27 CO distribution from corporation petrol four wheelers in 2058/59

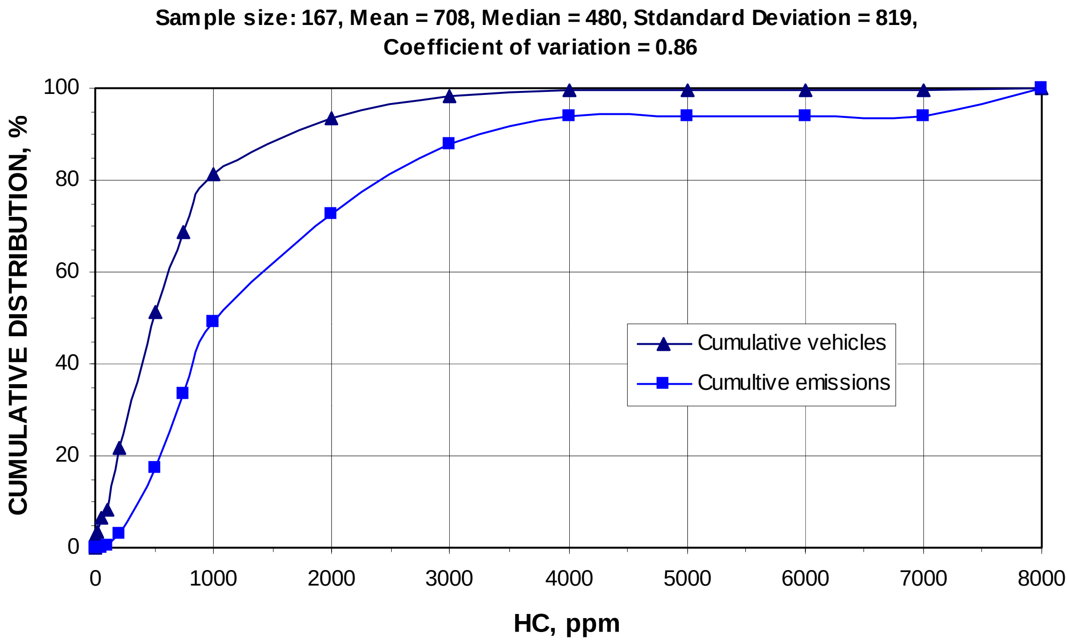

Figure C-28 HC distribution from corporation petrol four wheelers in 2058/59

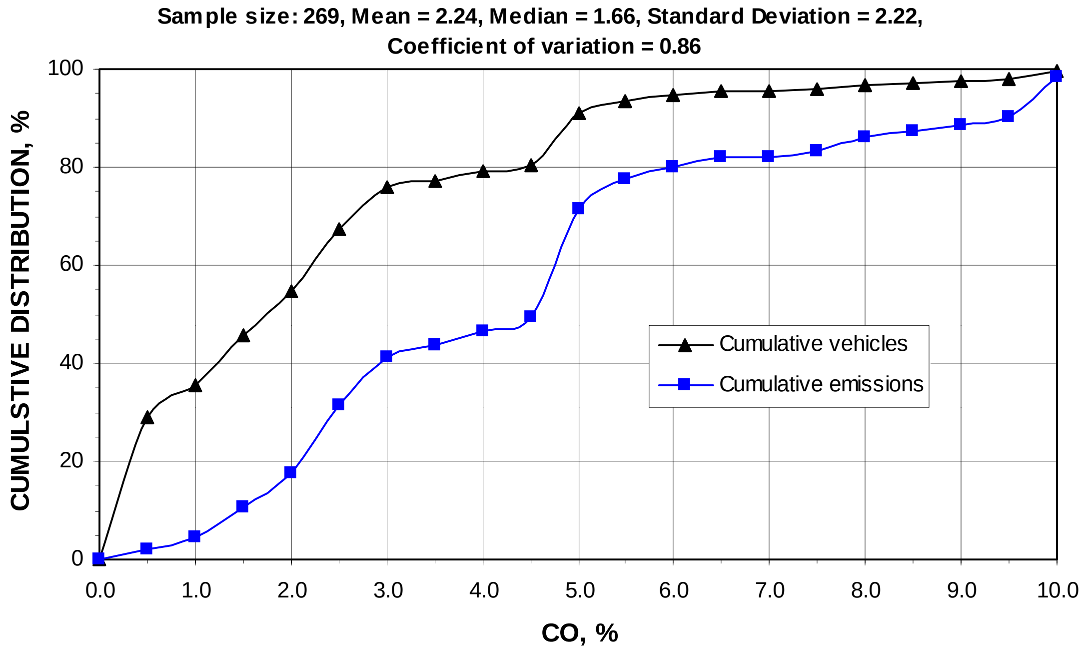

Figure C-29 CO distribution from tourism petrol four wheelers in 2058/59

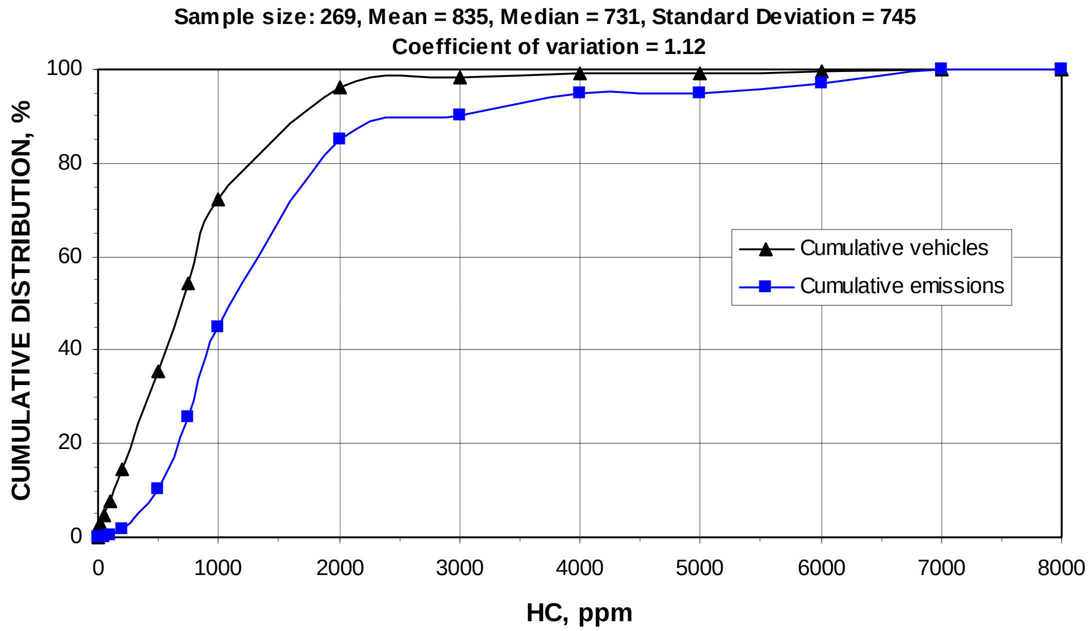

Figure C-30 HC distribution from tourism petrol four wheelers in 2058/59

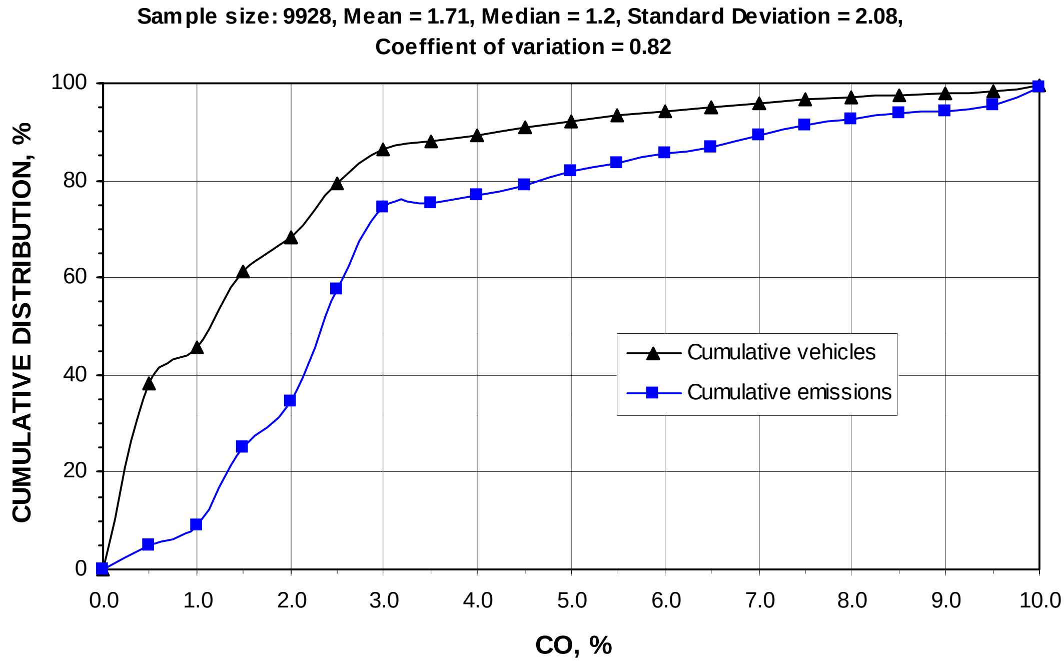

Figure C- 31CO distribution from petrol cars in 2058/59

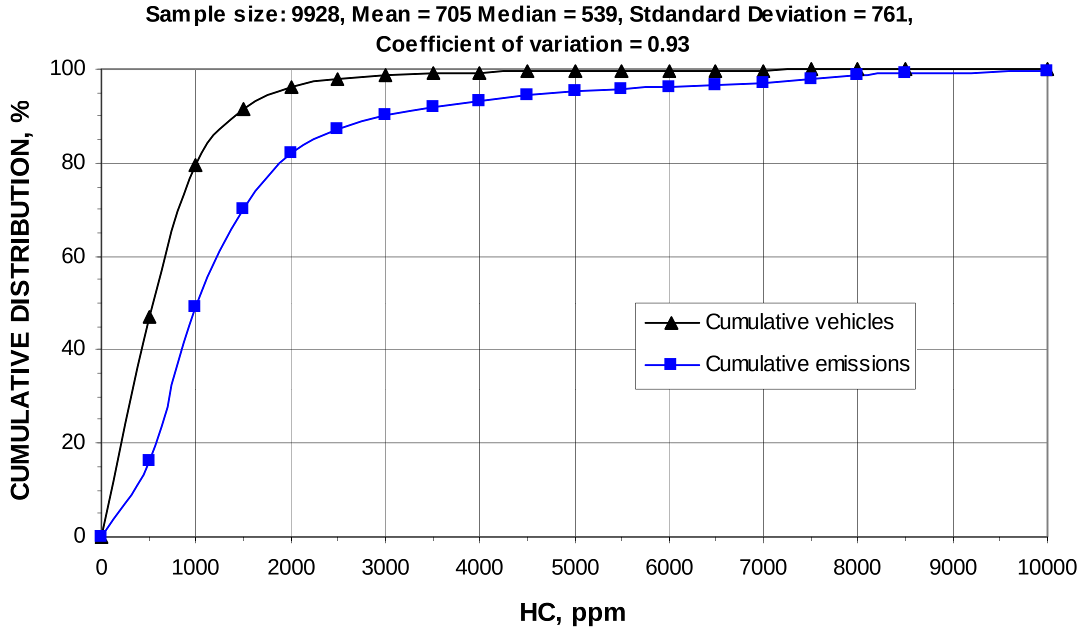

Figure C- 32 HC distribution from petrol cars in 2058/59

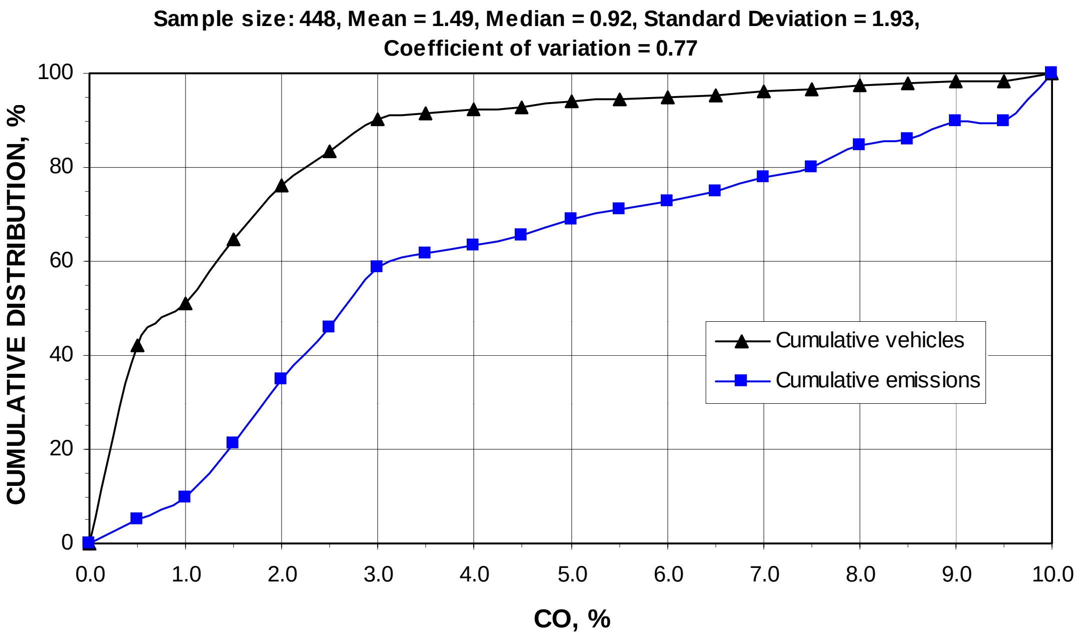

Figure C- 33 CO distribution from petrol jeeps in 2058/59

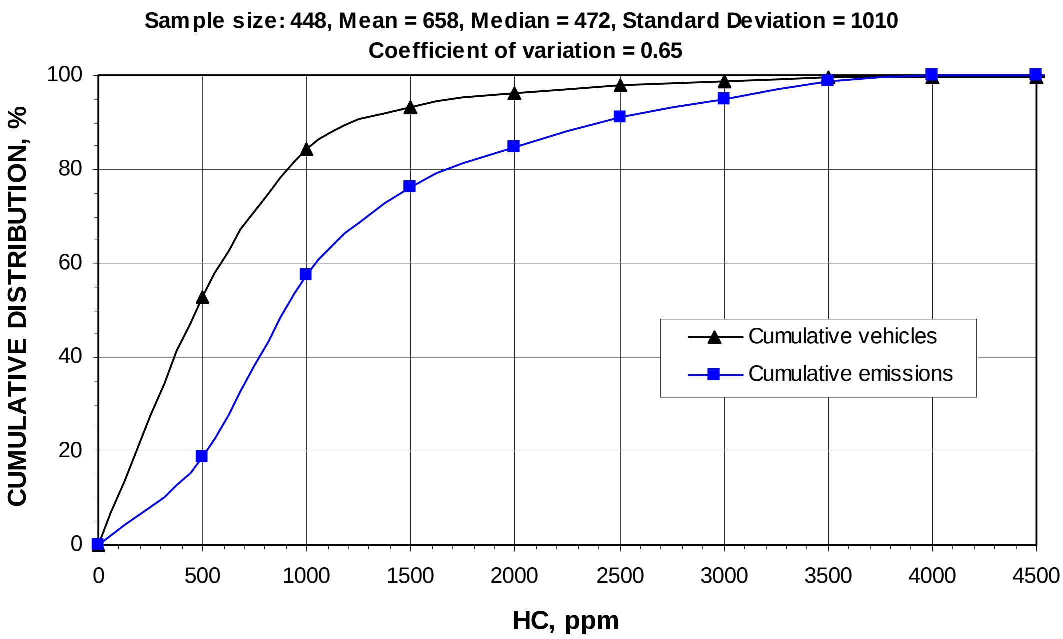

Figure C- 34 HC distribution from petrol jeeps in 2058/59

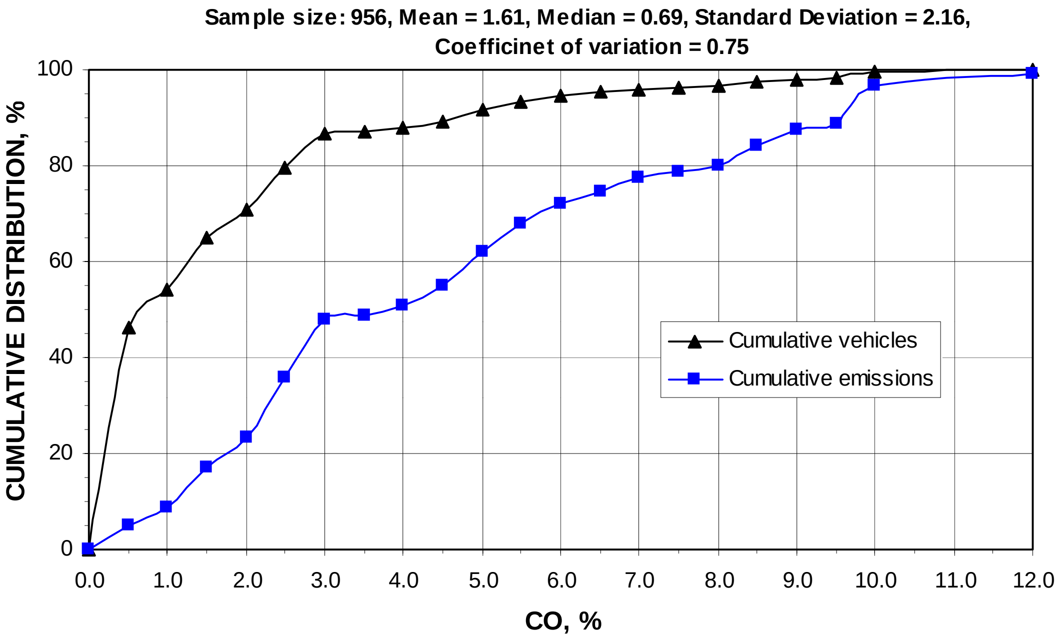

Figure C- 35 CO distribution from petrol vans in 2058/59

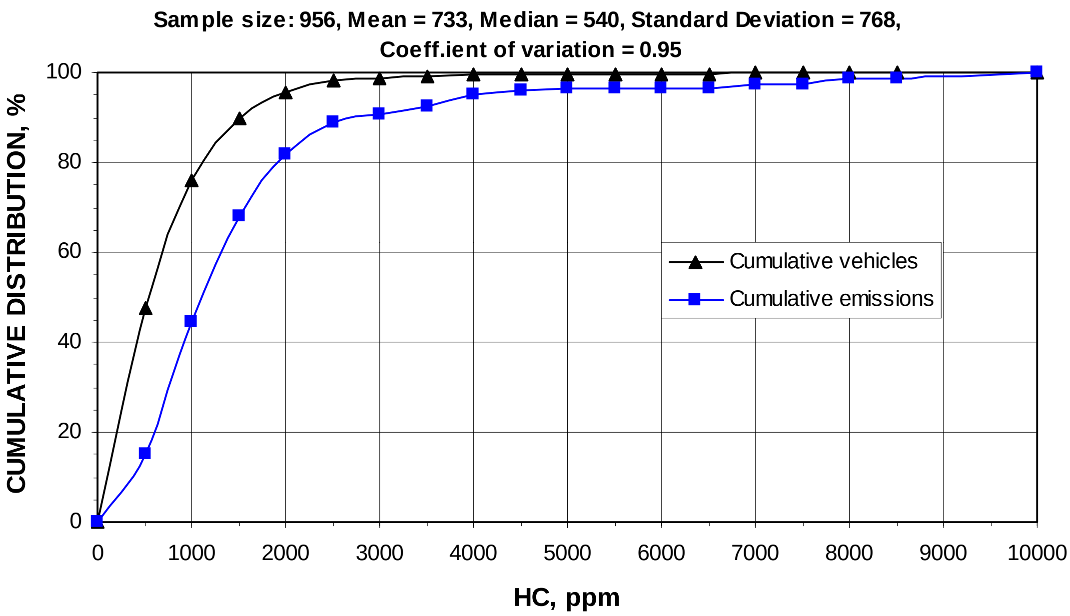

Figure C- 36 HC distribution from petrol vans in 2058/59

Appendix D: Cumulative distribution of emissions from diesel vehicles

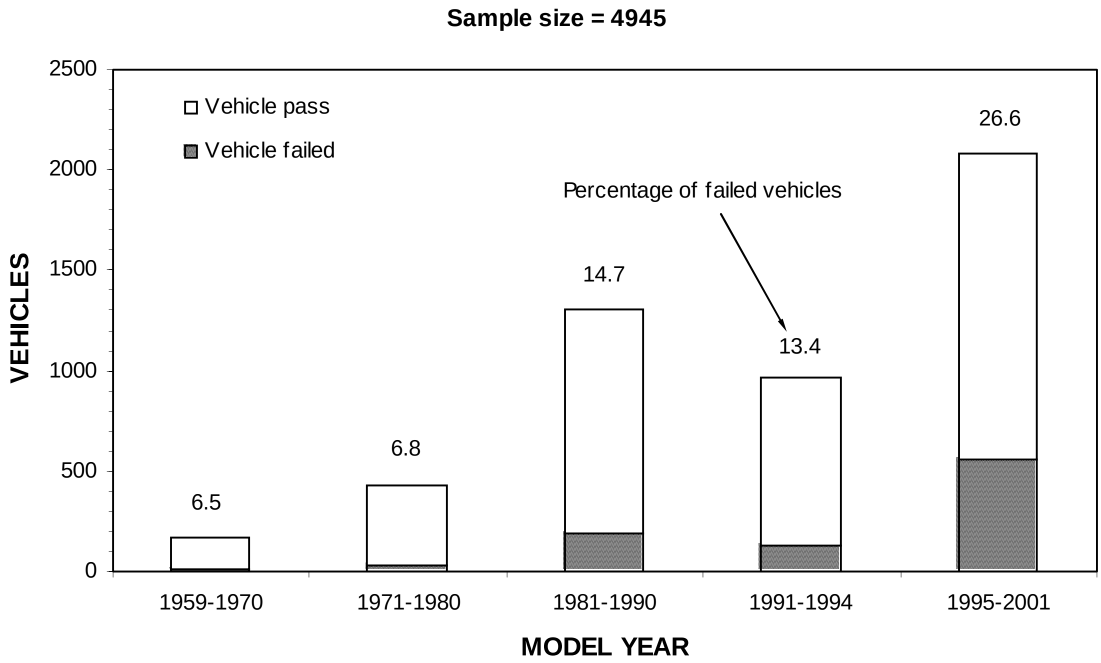

Figure D-1 Percentage of diesel vehicles by model year failed in 2058

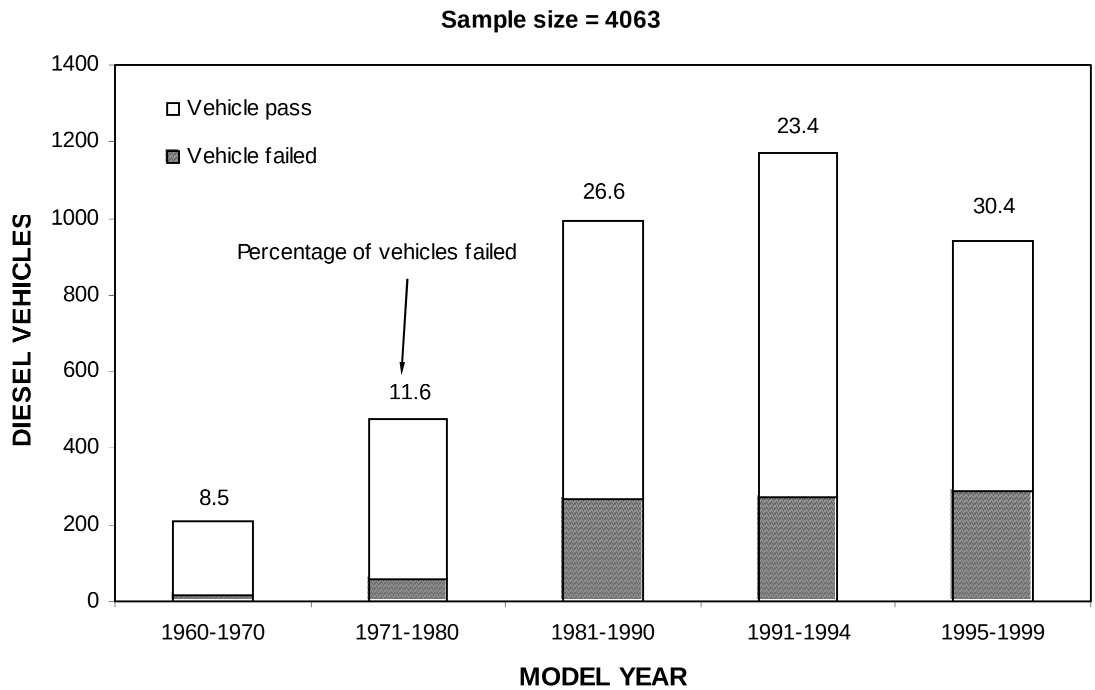

Figure D-2 Percentage of diesel vehicles by model year failed in 2059

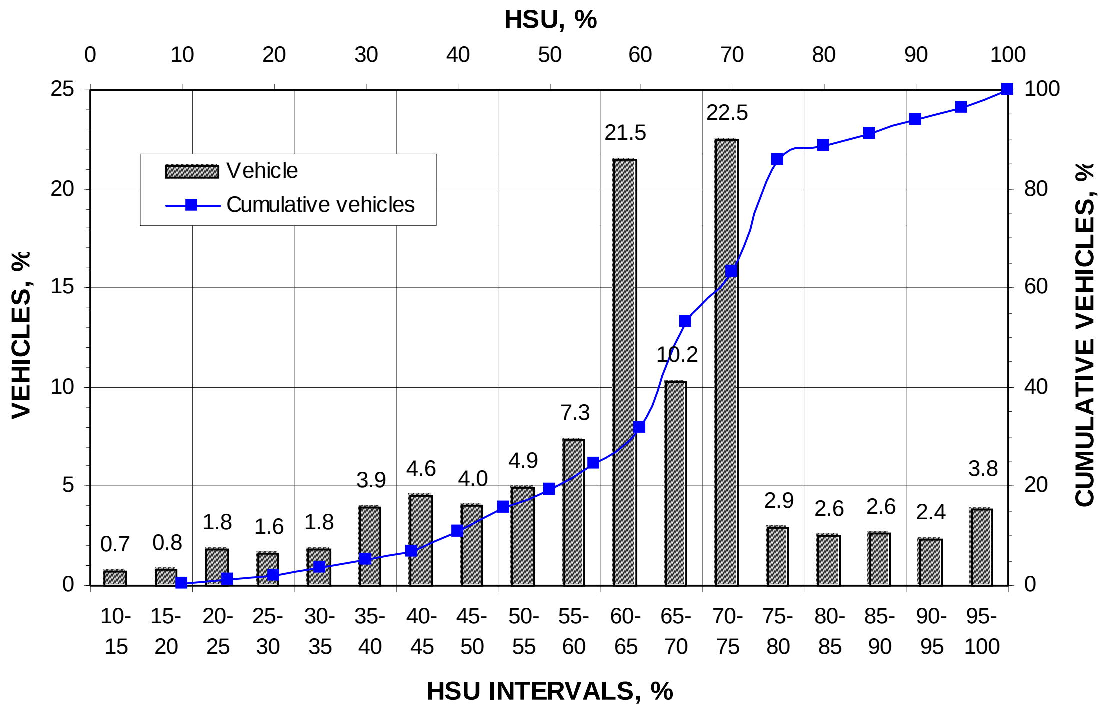

Figure D-3 HSU distribution from diesel vehicles in 2058

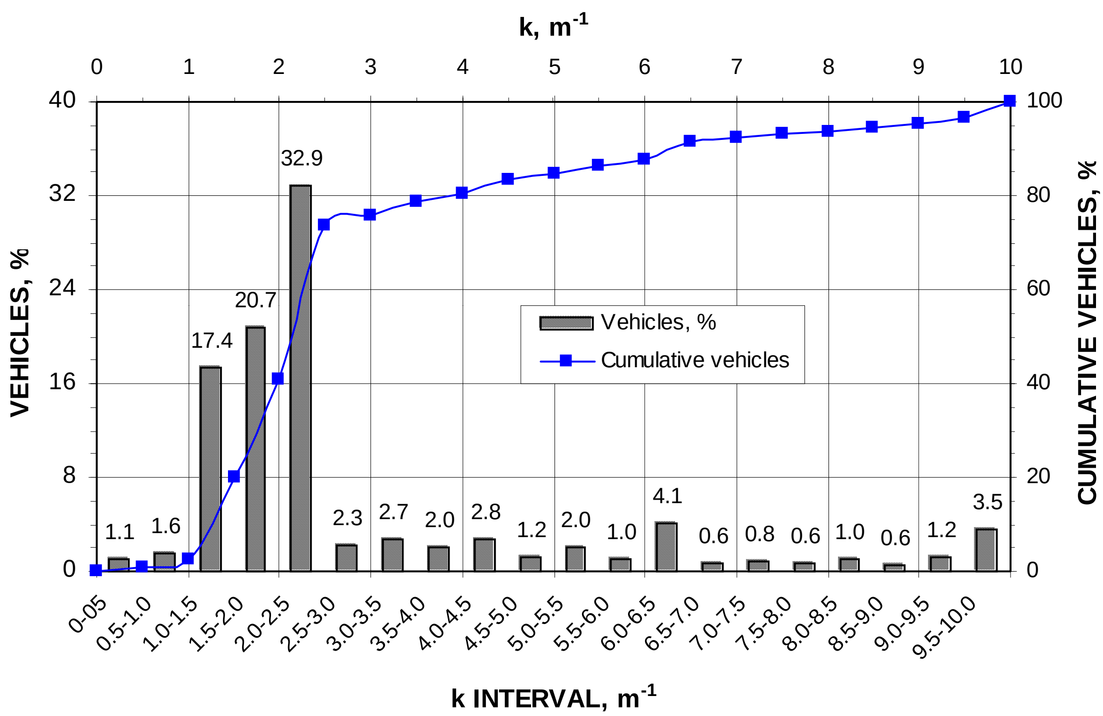

Figure D-4 k distribution from diesel vehicles in 2059

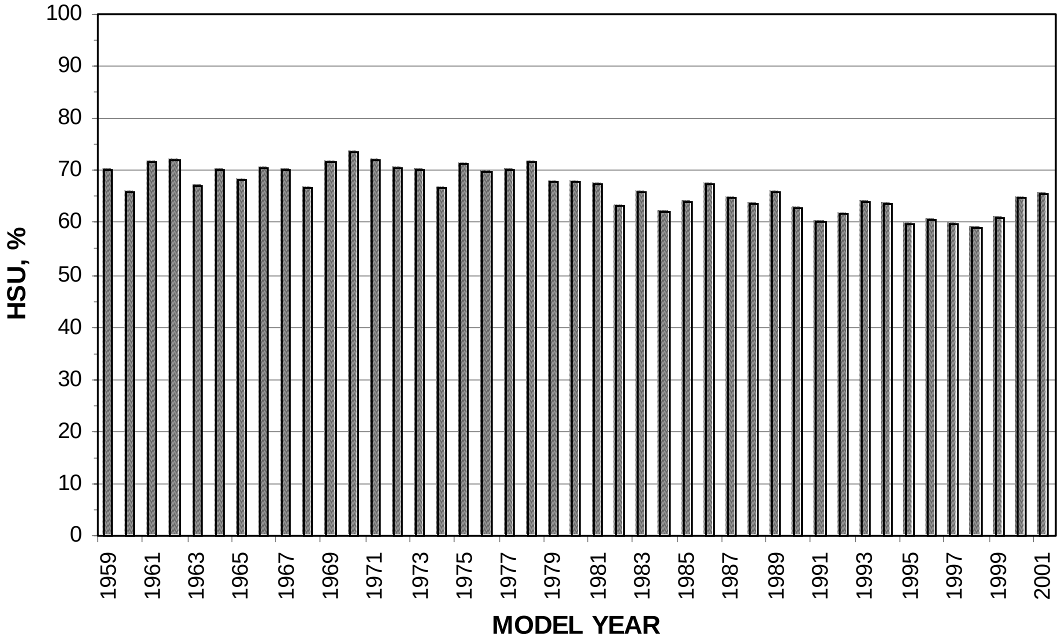

Figure D-5 Average HSU from diesel vehicles by model year in 2058

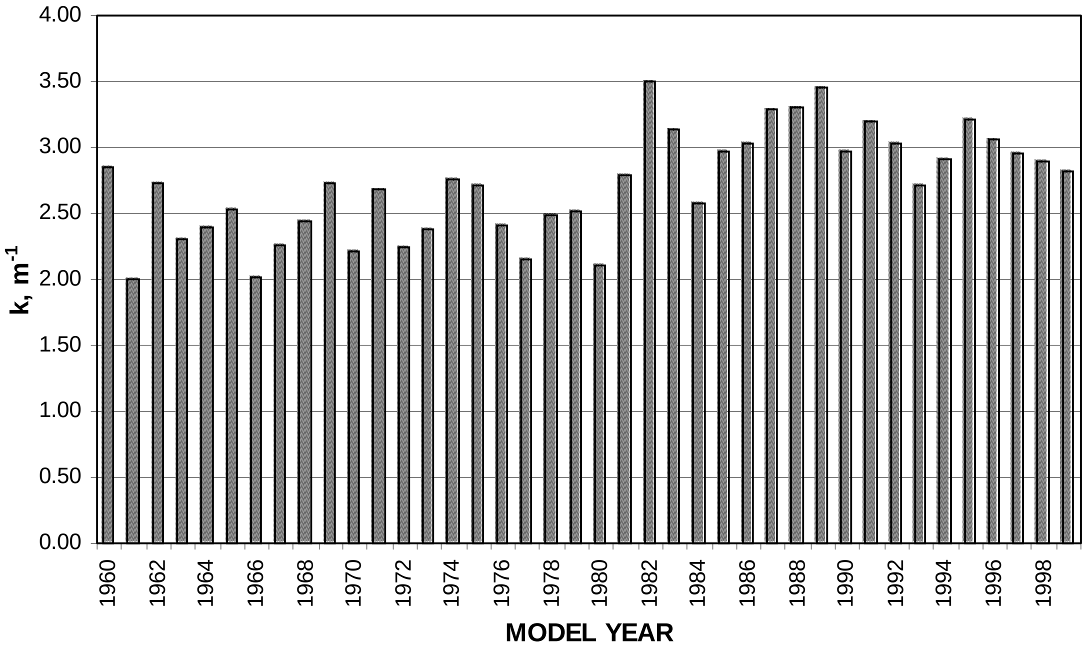

Figure D-6 Average k emission from diesel vehicles by model year in 2059

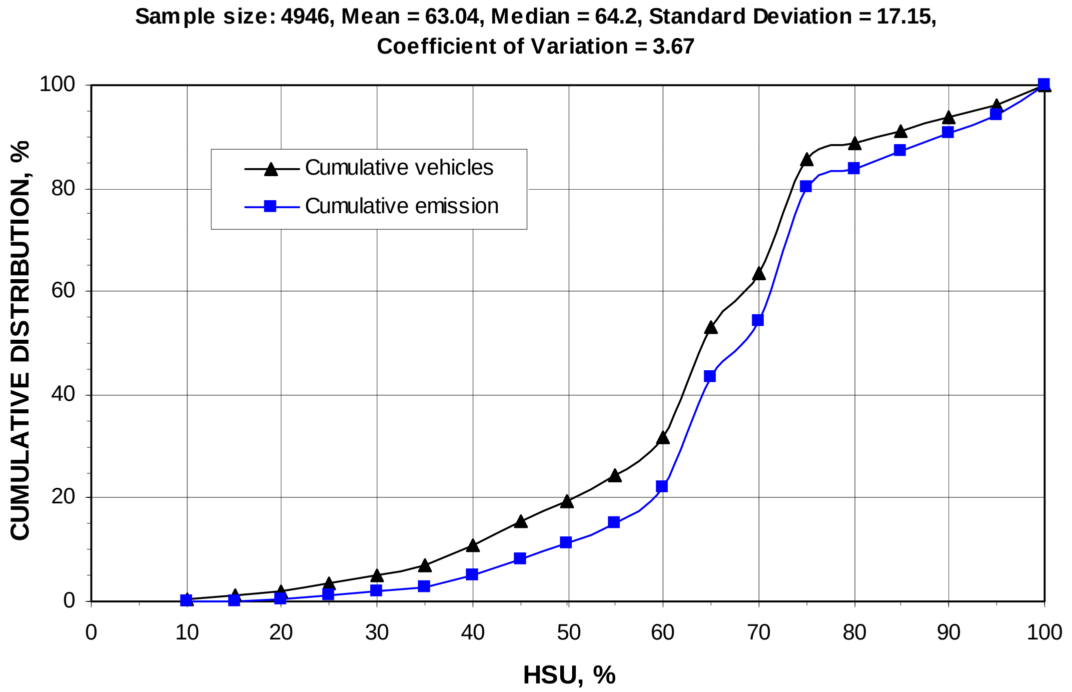

Figure D-7 HSU distribution from diesel vehicles in 2058

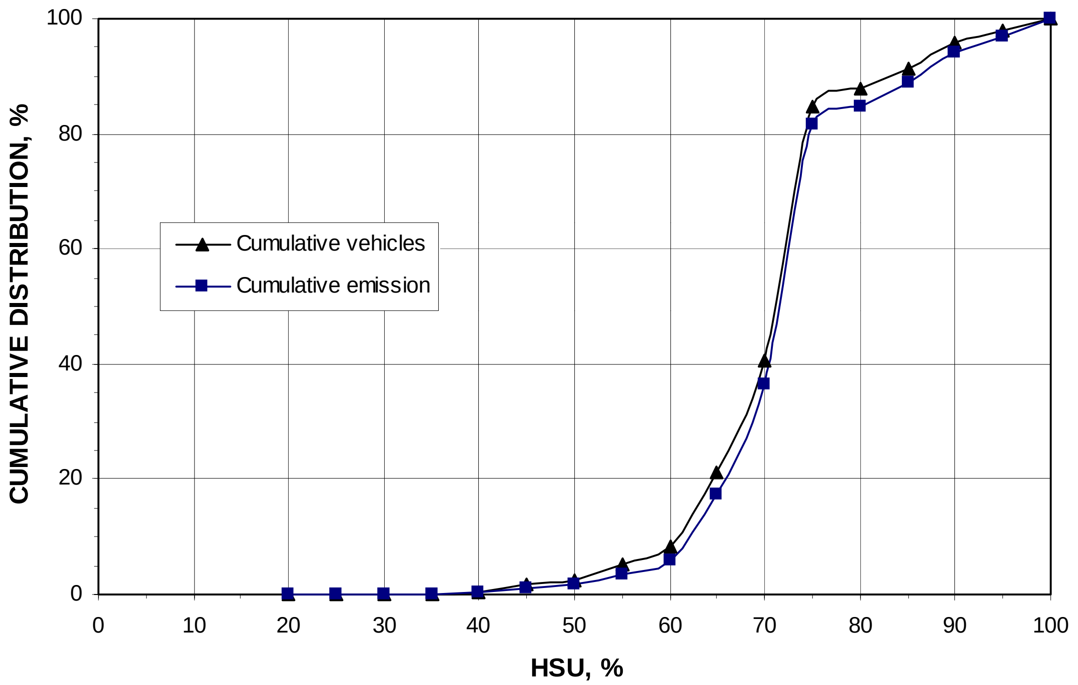

Figure D-8 HSU distribution from commercial diesel vehicles in 2057

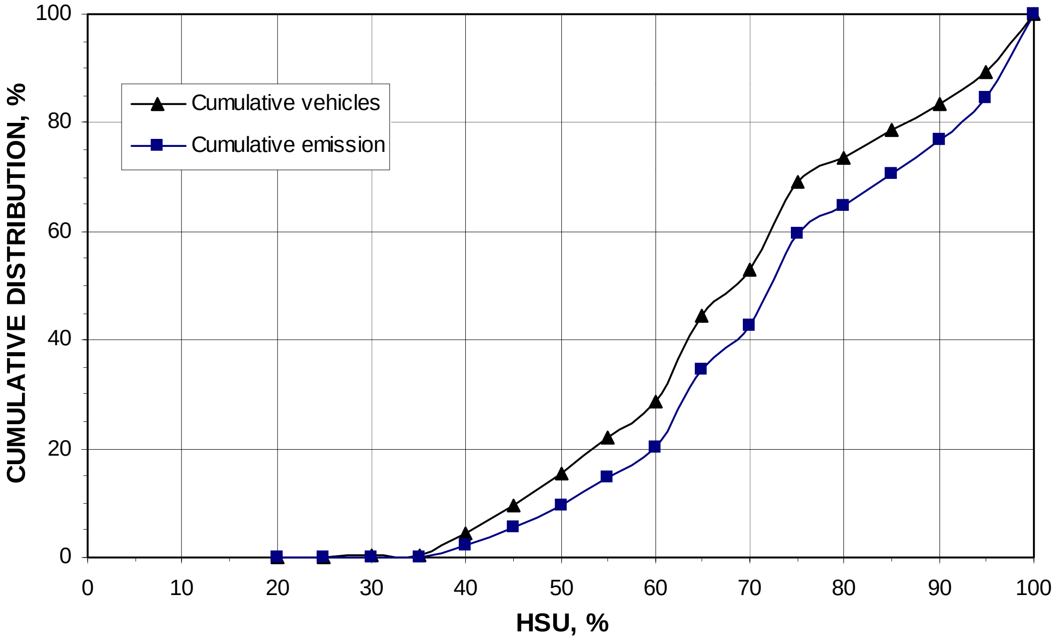

Figure D-9 HSU distribution from private diesel vehicles in 2057

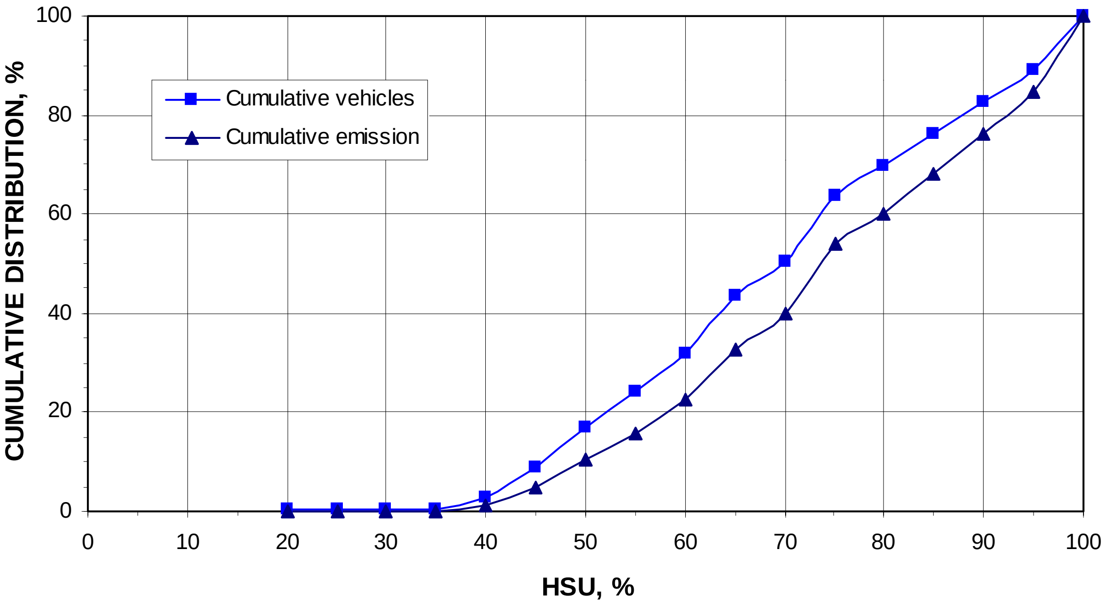

Figure D-10 HSU distribution from government diesel vehicles in 2057

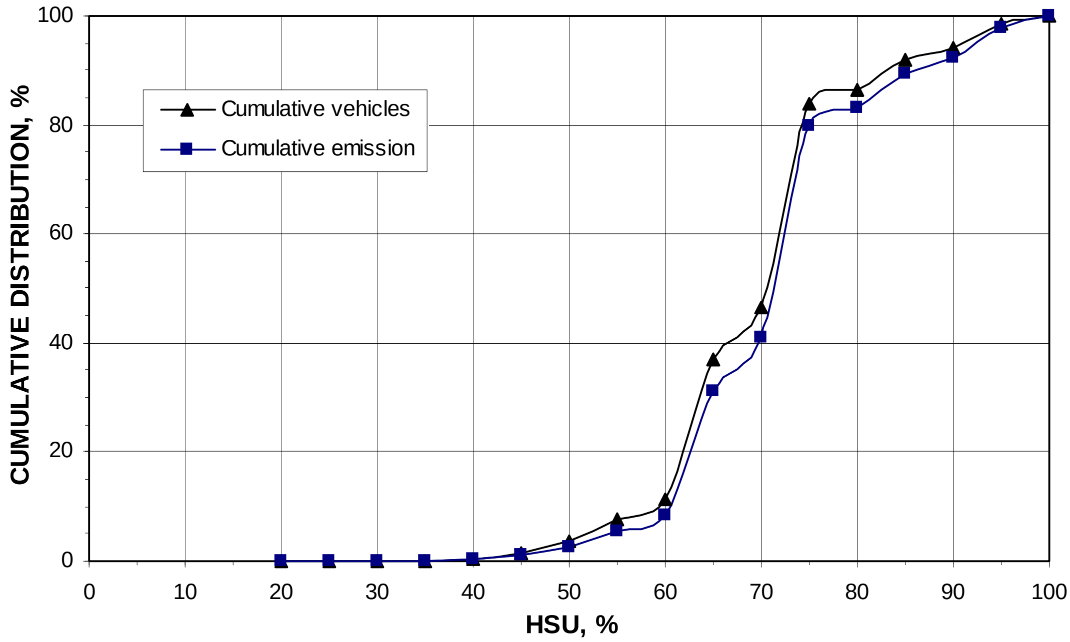

Figure D-11 HSU distribution from buses in 2057

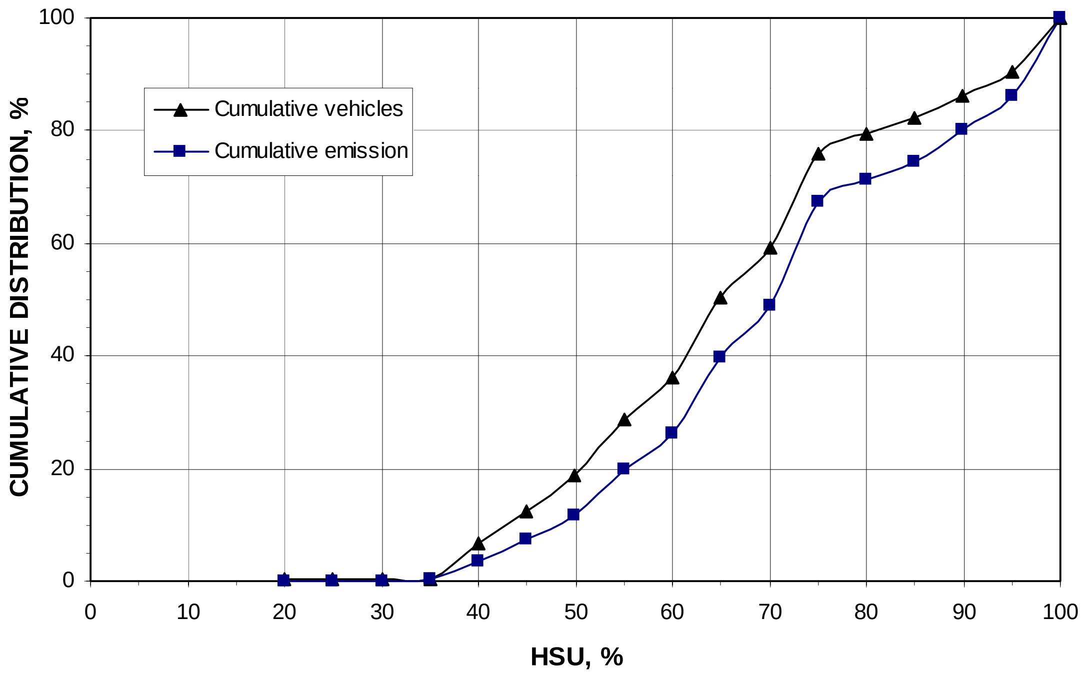

Figure D-12 HSU distribution from cars in 2057

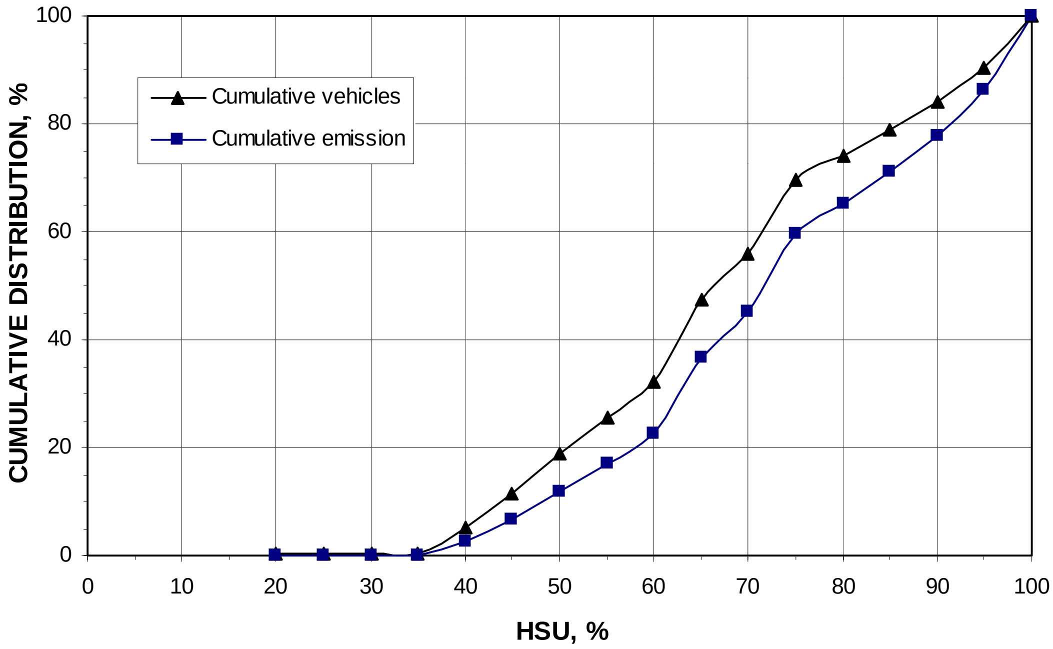

Figure D-13 HSU distribution from diesel jeep in 2057

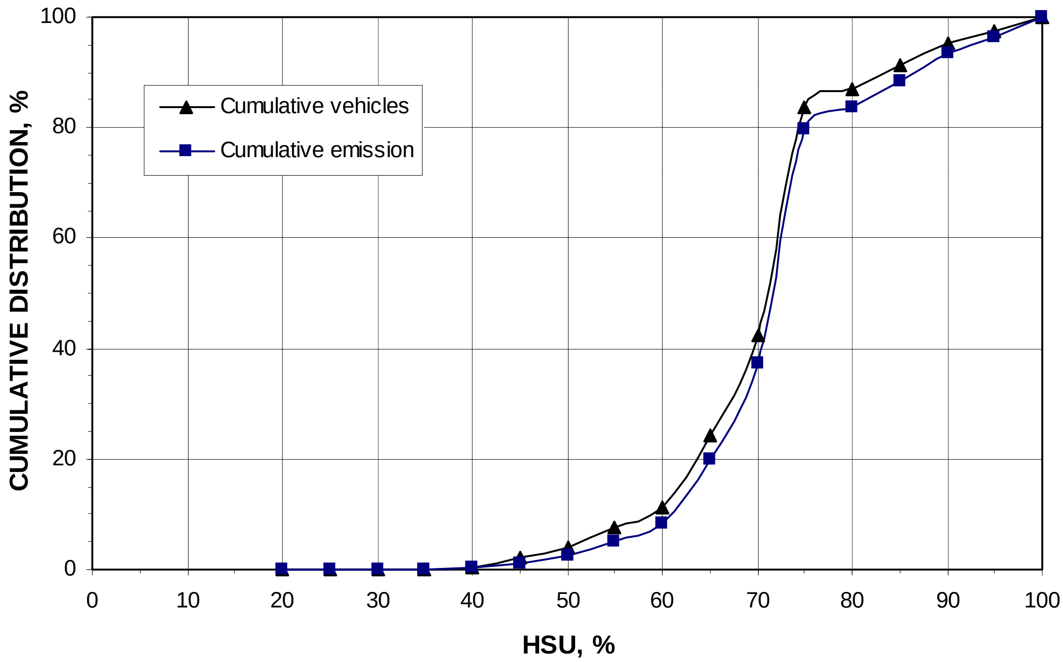

Figure D-14 HSU distribution from diesel minibuses in 2057

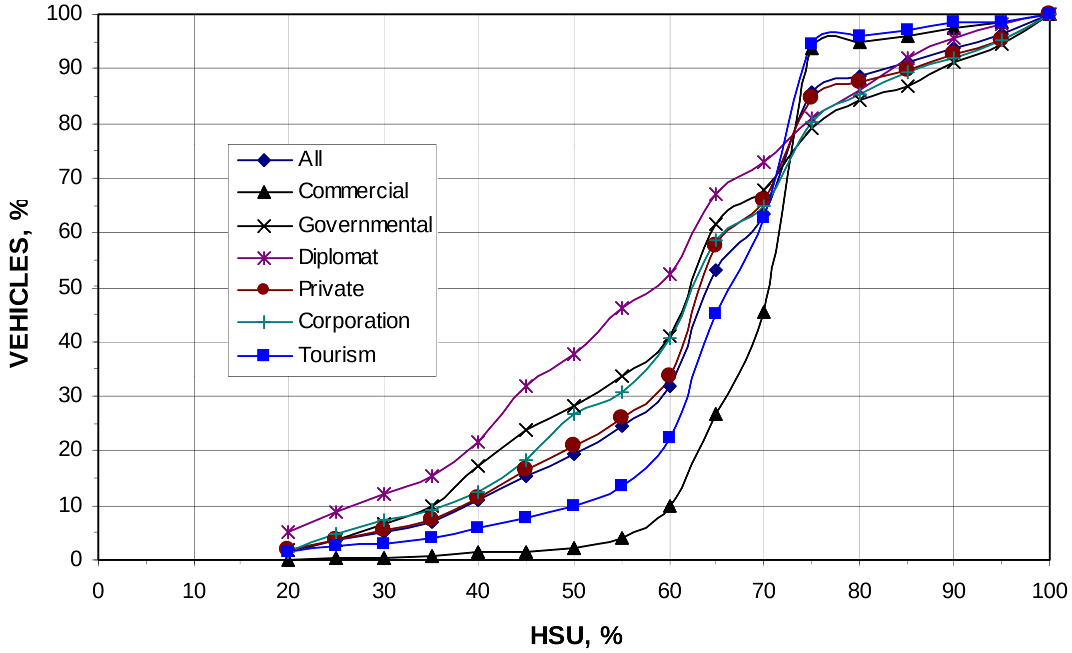

Figure D-15 Cumulative HSU distribution from diesel vehicles by category in 2058

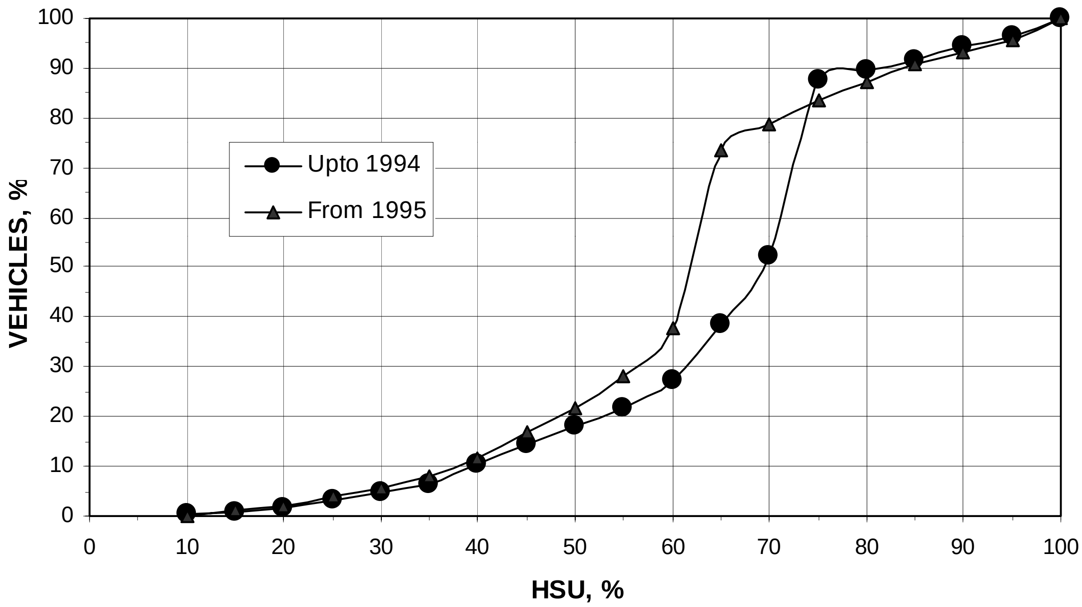

Figure D-16 Cumulative HSU distribution from diesel vehicles by model year up to 1994 and from model year 1995 in 2058

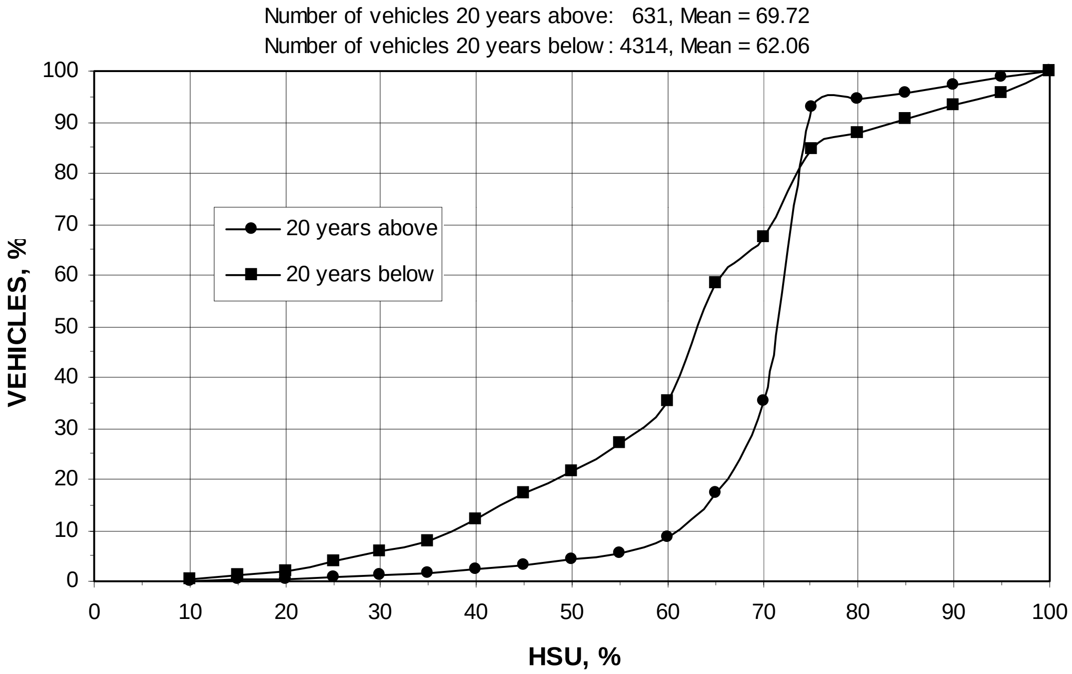

Figure D-17 Cumulative HSU distribution from diesel vehicles by age in 2058

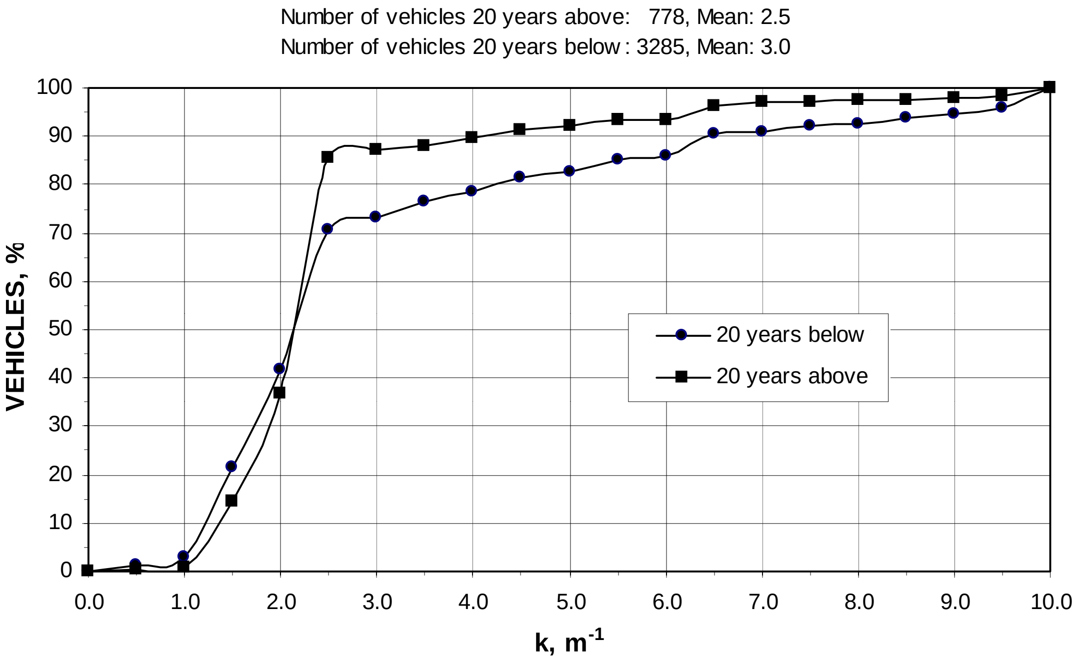

Figure D-18 Cumulative HSU distribution from diesel vehicles by age in 2059

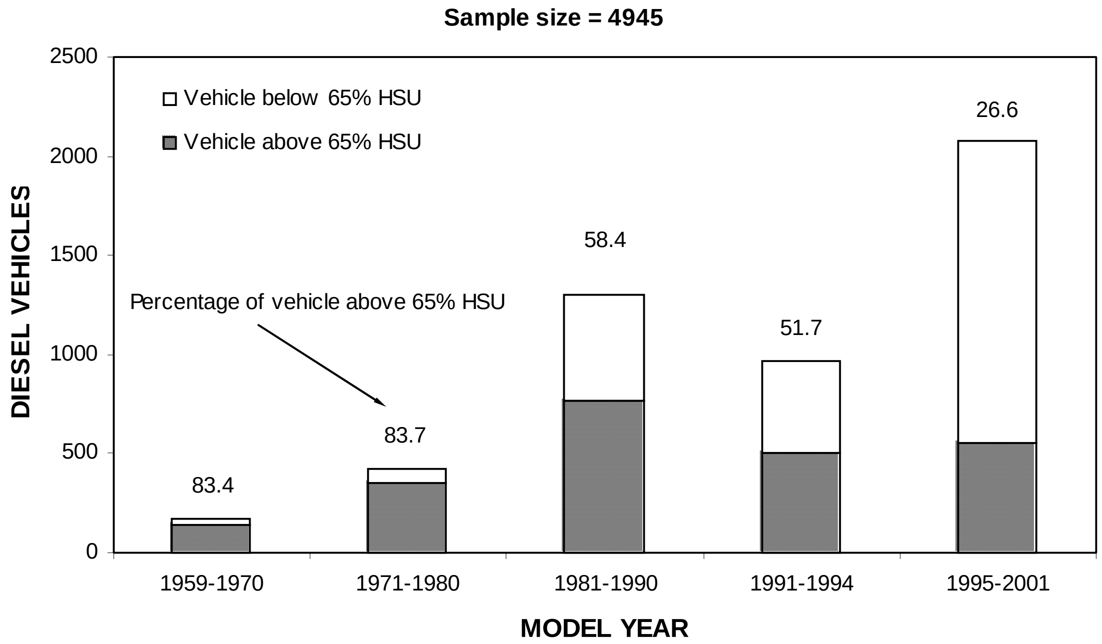

Figure D-19 Percentage of diesel vehicles by model year above 65% HSU in 2058

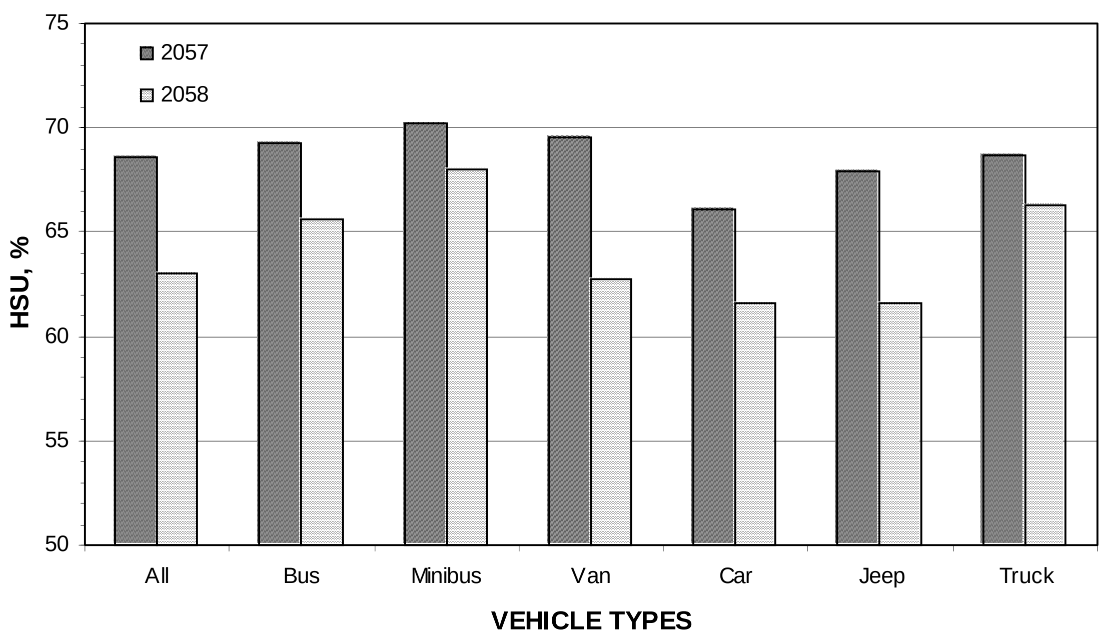

Figure D- 20 Average HSU from diesel vehicles by type in 2057 and 2058

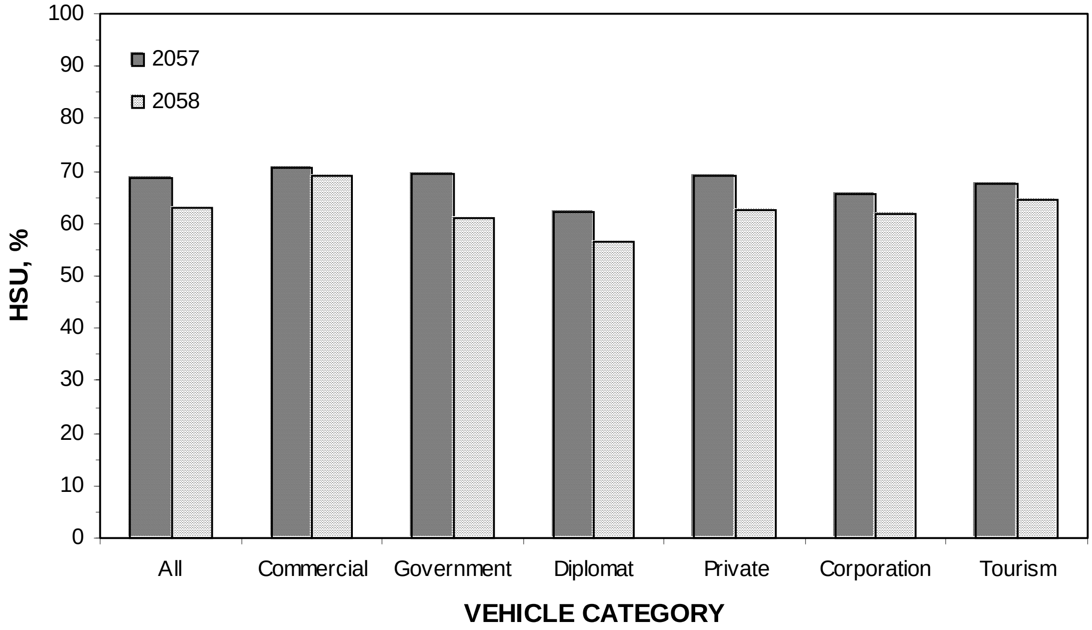

Figure D- 21 Average HSU from diesel vehicles by category in 2057 and 2058

Appendix E: HSU to k conversion chart

Note that HSU (Hatridge Smoke Unit) is the percentage opacity measurement for a column of smoke 430 in length. **k** is the coefficient of light absorption, a measure of 'blackness' of the smoke which is independent of the measurement length.

HSU, %	k, m^{-1}		HSU, %	k, m^{-1}		HSU, %	k, m^{-1}
0	0		33	0.93		66	2.51
1	0.02		34	0.97		67	2.58
2	0.05		35	1.00		68	2.65
3	0.07		36	1.04		69	2.72
4	0.09		37	1.07		70	2.80
5	0.13		38	1.11		71	2.88
6	0.14		39	1.15		72	2.96
7	0.17		40	1.19		73	3.04
8	0.19		41	1.23		74	3.13
9	0.22		42	1.27		75	3.22
10	0.25		43	1.31		76	3.32
11	0.27		44	1.35		77	3.42
12	0.30		45	1.39		78	3.52
13	0.32		46	1.43		79	3.63
14	0.35		47	1.48		80	3.74
15	0.38		48	1.52		81	3.86
16	0.41		49	1.57		82	3.99
17	0.43		50	1.61		83	4.12
18	0.46		51	1.66		84	4.26
19	0.49		52	1.71		85	4.41
20	0.52		53	1.76		86	4.57
21	0.55		54	1.81		87	4.74
22	0.58		55	1.86		88	4.93
23	0.61		56	1.91		89	5.13
24	0.64		57	1.96		90	5.35
25	0.67		58	2.02		91	5.60
26	0.70		59	2.07		92	5.87
27	0.73		60	2.13		93	6.18
28	0.76		61	2.19		94	6.54
29	0.80		62	2.25		95	6.97
30	0.83		63	2.31		96	7.49
31	0.86		64	2.38		97	8.15
32	0.90		65	2.44		98	9.10
						99	10.71

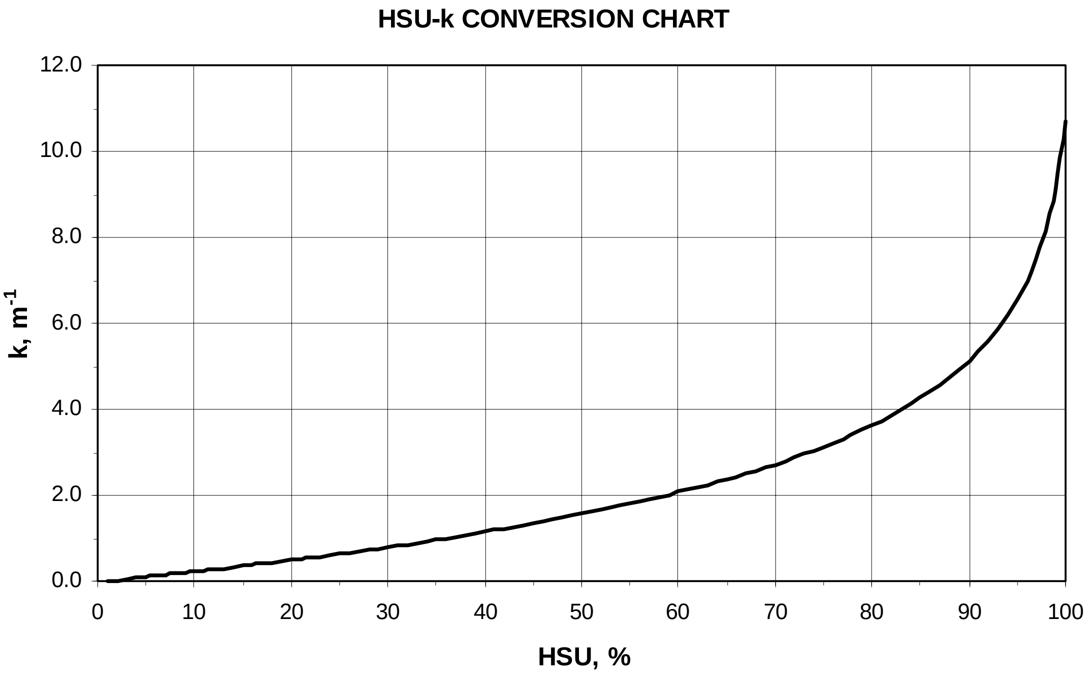

Figure E-1 HSU to k value conversion chart