Effect of Traffic Conditions on Fuel Consumption and Emission from Automobiles in Dhaka City

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DHAKA, BANGLADESH

August 2004

The thesis titled *Effect of Traffic Conditions on Fuel Consumption and Emission from Automobiles in Dhaka City* submitted by Md. Belayet Hossain, Roll No.: 100110012F, Session: 2001 – 02, has been accepted as satisfactory in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering on 25 August 2004.

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List of Symbols and Abbreviations

AQMP: Air Quality Management Project

BRTA : Bangladesh Road Transport Authority

CO : Carbon monoxide

CO_2 : Carbon dioxide

CNG : Compressed Natural Gas

DMP : Dhaka Metropolitan Police

DoE : Department of Environment

DUTP : Dhaka Urban Transport Project

EAM : Engine Analyzer Module

EPA : Environmental Protection Agency

EU : European Union

g/l : Gram per litre

HC : Hydrocarbon

HSU : Hartridge Smoke Unit

JBIC : Japan Bank of International Cooperation

TCM : Transportation Control Management

I&M : Inspection and Maintenance

kg/m^2: Kilogram per metre square

kPa : Kilo Pascal

mg/m^3	:	Milligram per metre cube
NA	:	Not applicable
NDIR	:	Non-dispersive Infra-red
NMHC	:	Non methane hydrocarbon
NO_x	:	Nitrogen oxide
Pb	:	Lead
PM	:	Particulate matter
ppm	:	Parts per million
psi	:	Pound per square inch
RVP	:	Reid vapour pressure
SO_2	:	Sulpher dioxide
SRDs	:	Setting and repair petrol vehicle data disks
TIP	:	Transportation Improvement Plan
TSP	:	Total Suspended Particles
t/yr	:	Ton per year
VES	:	Vehicle Emission Standard
VOC	:	Volatile Organic Compound
WHO	:	World Health Organization
% m/m	:	Percent by mass
% v/v	:	Percent by volume

Acknowledgement

With due sincerity, the author expresses his heartfelt gratitude and indebtedness to his thesis supervisor Dr. Maglub Al Nur, Professor, Department of Mechanical Engineering, BUET, Dhaka. His continuous guidance, close co-operation and invaluable suggestions encouraged the author to complete the research work. His advice, initiative, moral support and patience are very gratefully acknowledged.

Acknowledgements are also due to Dr. M. Zahurul Haq, Associate Professor, Department of Mechanical Engineering, BUET, Dhaka, for his valuable suggestions and kind co-operation.

The author particularly appreciates the sincere co-operation by Mr. A. K. M. Sirajul Islam, Director, City Service Center, Dhaka and Manager, Service Department, Navana 3s Center, Dhaka, from whom author collected experimental data and technical information.

Author also thanks the staff of Heat Engine laboratory and Measurement laboratory of Mechanical Engineering Department of BUET.

Abstract

Among other limitation/shortcomings, environmental problem in Dhaka city occur due to the lack of favorable facilities, such as, infrastructure of road network, insufficient traffic management, relaxation of traffic rules, coupled with the rapid rise in transportation demand. Air quality monitoring data is very limited in Dhaka city. Bangladesh notified the first emission standard under the environment conservation rules in 1997, but the standards are incomplete, have some inherent limitations and more importantly it has lack of strategies for proper implementations. In Dhaka, there are no facilities for measurement of emissions from in-service or on-road vehicles.

In the present study, simulated on-board measurement has been carried out on six vehicles. The test was executed at the center of Dhaka city under various traffic conditions. All the vehicles comprising gasoline engine were measured for both fuel consumption and emission. The main emphasis was put on driving in the peak hours (morning and evening) and off-peak (noon) traffic conditions. The principal aim is to obtain realistic fuel consumption and exhaust emission data for Dhaka city. Secondly, to establish the relationship between consumption and emissions under various traffic conditions. The collected data may be fed into a simulation model that would evaluate traffic management concepts to reducing fuel consumption and emission levels of cars.

CHAPTER – ONE

INTRODUCTION

Motor vehicles emit large quantities of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), fine particulate matter (PM) and lead (Pb). Each of these, along with secondary by-products such as ozone, cause adverse effects on human health and the environment. Because of the growing vehicle population and high emission rates from many of these vehicles, serious air pollution and health problems have become increasingly common phenomena in modern life. Reducing pollution from vehicles usually requires a comprehensive strategy. Generally, the goal of a motor vehicle pollution control program is to reduce emissions from new and in-use motor vehicles to a degree reasonably necessary to achieve healthy air quality as rapidly as possible. Failing that for reasons of impracticality, the goal is to meet the practical limits of effective technological, economic, and social feasibility. A comprehensive strategy to achieve this goal includes four key components: (i) increasingly stringent emissions standards for new vehicles, (ii) specifications for clean fuels, (iii) programs to assure proper maintenance of in-use vehicles, and (iv) transport planning and travel demand management [1]. These emissions reduction goals should be achieved in the most cost effective manner available.

Transportation and air quality managers have task of developing and evaluating Transportation Control Measurements (TCMs) and other types of Transportation Improvement Plans (TIPs). One of the objectives of TCMs and TIPs is to improve the air quality. The benefits of many TCMs and TIPs accrue at the "micro" level, such as, individual signalized intersections, traffic control devices, roadway facilities improvements (e.g., ramps, roundabouts), improved incident response and management and others [2]. In order to evaluate the air quality benefits of such projects , it is necessary to evaluate localized changes in emissions at a fixed location. Alternatively, in order to evaluate air quality benefits of alternative routing schemes, one must evaluate changes in emissions associated with substituting one route for another between the same origin and destination. Finally, in order to assess the larger scale benefits of regional management strategies, there must be good, representative, and real-world data regarding on-road emissions for a variety of facility types and control devices.

The data required to accurately assess the air quality benefits of TCMs and/or TIPs must be real-world on-road data and must also be of sufficient temporal and spatial resolution to enable identification and evalution of hotspots, measurement of changes in emissions as a result of specific, local TCMs (e,g. improved traffic signal coordination and timing) and yet be amenable to the development of datasets to assess regional emissions trends. However, existing highway vehicle emission factor models, such as the Mobile5b or EMFAC7 series of models, are based upon assumed standardized driving cycles. The data input to these models is in a sense "hardwired" to represent only a selected set of origin-to-destination trips. These models are routinely misapplied to attempt to characterize link-based emissions (e.g., emissions for a short section of roadway) or even to extrapolate idling emissions. For example, the “slowest” driving cycle in the Mobile5a model is the LSP1 cycle, with an average speed of approximately 2.5 miles/hr. This cycle includes many starts and stops, and therefore includes idling, acceleration, deceleration, and limited amounts of cruising. An average emission rate for this cycle is typically converted from a gram of pollutant emitted per mile of distance traveled basis to a gram of pollutant emitted per time elapsed basis, and assumed to be representative of idling emissions [3]. However, in our country no standard “highway vehicle emission factor models” are being followed at present.

In the present work, an empirical approach to measure real-world, on-road vehicle emissions is emphasized. The specific method employed here, based upon instrumentation of individual vehicles and measurement of tailpipe emissions, offers the benefits of providing second-by-second vehicle activity and emissions data, which enables characterization of emissions at any time or location during a route. With on-road data of high temporal and spatial resolution, it is then possible to evaluate the local effect of TCMs and TIPs, as well as to design and implement studies aimed at characterizing actual emissions.

1.1 Objectives

So far, no on-board measurement has been carried out to measure the fuel consumption and emissions in Dhaka city. The present investigation performs simulated on-board measurement for both fuel consumption and emissions of CO, HC, and NO_x. The specific objectives of the present research are as follows:

- To obtain real fuel consumption and emission figures for passenger cars in Dhaka city.
- To gain an insight into the relationship between the fuel consumption and emissions under different traffic conditions

The collected data may be used as a simulation input that would evaluate traffic management concepts with a view to reducing fuel consumption and emission levels of cars.

CHAPTER - TWO

LITERATURE REVIEW

2.1 Introduction

The automotive technology has advanced a long way since it's first true development in the beginning of the 20^{th} century by Henry Ford. The society has used technology in order to help advance the automobile to make it better and more efficient. People have always had a need for speed, a need to have the best of the best, and a need to have the newest trend. And that is what major automobile industries have been giving the society because they know that they can profit greatly from it. In order to improve automobiles so that they meet these needs of our society, automobile industries turned to technology. Technology is what has turned the Ford model T into a Ford Mustang 5. The human comport and technology comes with a price. The biggest and most obvious price is pollution. Because of pollution, people asking the question of whether this technology has helped our society more than it has hurt it.

There are four main sources of pollutants that come from an automobile [3]. The first source is referred to as diurnal. On a hot day, the sun will heat up the gasoline tank of a car. This in turn, causes gasoline vapours to vent from the fuel tank. Running losses simply occur because when the car is running its engine become heated. This in turn causes the engine and exhaust system to vaporize gasoline. After a car is turned off and parked, gasoline continues to evaporate into the atmosphere because the engine is still hot from running. This source is referred to as a hot soak. And lastly, when we refill our fuel tank, vapour in the fuel tank are forced out in the refueling process.

Automobile pollution is a direct result of the combustion process (exhaust) and also from the fuel being evaporated into the atmosphere. When we put gasoline into our car, we are putting a mixture of hydrocarbon into our car which contain hydrogen and carbon atoms. What was intended to happen is the oxygen in the air was supposed to convert all the hydrogen in the fuel to water and all of the carbon in the fuel to CO_2. But what really happens is that there are HC atoms left over from the combustion process because they do not burn or only burn partially. Other pollutants that are given off through the emissions of automobiles along with the hydrocarbons are NO_x, and CO.

All of these automobile pollutants affect the environment in different ways. But one thing that they all have in common is that their effect on the environment is a negative one which in turn affects humans in a negative way also. The most dangerous and widespread of the pollutants are HC. Hydrocarbons emitted by automobiles create smog by reacting with NO_x and sunlight. This smog acts as a ground level ozone that cause many health problems for people. These problems include eye irritation, lung damage, and respiratory problems, HC can even cause cancer which can lead to death [4].

NO_x are like hydrocarbons in that they also play a part in the destruction of the stratospheric ozone layer. Due to the high temperature in the automobile's engine, nitrogen and oxygen atoms in the air react and form this NO_x. Along with deteriorating the ozone, NO_x also help to form acid rain which hurts plants and other wildlife.

When incomplete combustion occurs because carbon is not completely oxidized to form CO_2, CO is formed. Carbon monoxide is very dangerous to human health. It reduces the flow of oxygen in the bloodstream and in turn can be extremely dangerous to those people with heart disease. The CO_2 that is supposed to form in the combustion process also becomes a serious environmental problem in that it is a "greenhouse gas" that acts as a contributor to global warming .

2.2 Air pollution and the engine

Pure air is best defined as a mixture of nitrogen and oxygen with traces of rare gases like argon, neon, etc; atmospheric air contains, in addition, water vapor, carbon dioxide, other gases, and various suspensions of fine solid or liquid particles called ' aerosols'. Since no absolute composition can be defined, air is always 'polluted' – the problem is to minimize the pollution. A noted meteorologist predicted recently that polluted air could put an end to the life on this planet within the century [5].

There are two general types of aerosols; 'neutral particles', dust from rocks, manufacturing processes, soot and fly ash, etc; and 'condensation nuclei' made up of hygroscopic substances such as chloride salts, sulphur oxide, oxides of nitrogen, etc. The chief sources of dust are from windstorms and volcanic eruptions – not man-made (In February 1903 nearly 10 million tons of red dust from the deserts of north Africa were deposited over England.) Although dust is a nuisance, the more important suspensions are those arising from condensation nuclei. These substances, because of their hygroscopic nature, furnish the surface for the process of condensation (and thus lead to fog, clouds, and eventually, rain, in our normal living program). Non hygroscopic particles can also serve as condensation nuclei but only if the atmosphere is greatly supersaturated with water vapour.

Starting in the fourteenth century with the growing use of coal, and accelerating with the industrial revolution, air pollution from combustion became a serious problem. The name 'smog' originated in England around 1911 as a synonym for the mixture of fog and coal smoke that often blanketed London and Glasgow. In 1952 several thousand people died in London from the effect of a particularly severe smog blanket, and many thousand more exhibited serious respiratory ailments.

The more difficult problem is the automotive engine, because (a) it is small, and therefore rarely serviced properly; (b) it is operated accelerating and decelerating under various conditions of loads and speeds; (c) it has millions of prototypes on the highways. For the 178 billion gallons of gasoline and fuel oil consumed in the USA in 1967, the products (in tons) discharged into the atmosphere were shown (approximately) below [5]:

Carbon monoxide	170,000,000 tons
Hydrocarbons	30,000,000 tons
Nitrogen oxides	9,000,000 tons
Aldehydes	400,000 tons
Sulfur compounds	800,000 tons
Organic acids	180,000 tons
Ammonia	180,000 tons
Solids	27,000 tons

The foregoing amount of CO, if it were not dispersed and digested by natural means, would yield a concentration of 30 ppm over the entire area of the USA to a height of 2000 ft.

2.3 Vehicle Emissions

Walsh [6] made a study for global trends in the use of motor vehicles and emission. It was pointed out that including commercial vehicles, more than one half of a billion vehicles are now on world's roads which is ten times more than those were in 1950. The author identified that vehicle emissions, HC, CO and NO_x are the major sources of climatic change. Emissions create adverse effects to health and environment on the ground level. In addition, tropospheric pollution and climatic changes found to be directly linked by a variety of mechanisms that work against lives. On a global scale, emissions of these pollutants depend on the number of vehicles in use and their emission rates. In turn, the actual emission rates depend on fuel efficiency and use of available control technology.

Danielis et al. [7] shows that in Italy, 6,162 people would die in the cities above 20,000 people because of exposure to transport-related Total Suspended Particulates (TSP) pollution. They account for 0.00020% of the cities population (city's population was 30,013,973). The largest number of death (44%) takes place in cities with a population size of more than 500,000 people city size, though only 17.2% of the population lives there. Therefore, living in a big city puts life more at risk. The authors [7] also show that diesel vehicles are the largest contributors (95.2%) to PM10 emission, while gasoline vehicles contribute only 4.4%. Within the diesel vehicles, light-duty vehicles and heavy-duty vehicles share an equal responsibility. They [7] further show that the cost per vehicle-kilometre varies a lot among vehicle-types and city size. On average, CNG cars impose in urban areas a cost of 13.7 cents of (1992 US $) per km, while gasoline cars impose a cost of 17.7 and diesel vehicles of 540.3 cents (1992 US $). Diesel vehicles (mainly trucks, trailers and buses) are the ones which impose the largest cost on society. Their external cost is 30 times higher than that of gasoline cars. Within gasoline cars, the cost per km varies with engine size: cars with less than 1400 cc impose half the cost of cars with more than 2000cc. And within diesel vehicles, light-duty vehicles (cars and small trucks) impose a cost 6 times lower than heavy-duty trucks and buses.

De Vlieger [8] shows at rush hour the fuel consumption of passenger cars went above 10 km/ltr, even for diesel cars. Consumption was 20 to 45% higher in the rush hour than that in smooth-flowing traffic condition. He [8] also shows that during the rush hour, CO_2 emissions are 20 to 45% higher than in smooth-flowing traffic. The CO and the HC emissions are 80% higher and the NO_x emission 50% higher during rush hour than in smooth-flowing traffic [9].

Frey et al. [10] show that that the emissions during the acceleration mode are significantly higher than for any other driving mode, for all four of the pollutants measured. Conversely, the emission rate during idling is the lowest of the four (HC, NO_x, CO and PM) modes for all four pollutants. The cruising emission rate is typically slightly higher than the deceleration emission rate. For each of the four pollutants, the four modal emission rates are significantly different from each other at 0.05 significance level, except for cruising and deceleration emissions of CO.

CHAPTER – THREE

AIR QUALITY IN DHAKA CITY

3.1 Introduction

Environmental problems in all major cities of Bangladesh occur due to the lack of favorable facilities, such as infrastructure of road network, coupled with the rapid rise in transportation demand. It is also caused by the large number of non-motorized vehicles on roads, lack of application of adequate and proper traffic management schemes, industrial growth, construction activities, resuspension of dusts, and open burning. Ever increasing traffic congestion in the streets, use of leaded gasoline and high content of sulfur in diesel enhance suffering of inhabitants of major cities from vehicle emissions. This demands a study for Dhaka and other major cities in developing infrastructures and improving air quality.

3.2 State of Air Quality in Dhaka

Air quality monitoring data is limited in Dhaka, however, periodic surveys by the Department of Environment (DoE), indicate that the ambient levels of SPM, SO_2, and airborne lead are higher than the Bangladesh air quality guidelines. Based on the air quality data of DoE, ambient levels of SPM exceeds Bangladesh air quality standard in commercial and mixed areas throughout the year, while the SO_2 level exceeds the standard during the dry winter season. The NO_x levels appear to be under acceptable limit of the air quality standard. However, Bangladesh standard is not directly comparable with the international air quality standard because of differences in averaging time, but in general SPM and SO_2 exceeds international standard of ambient air quality during the whole year in Dhaka. Lead content in ambient air was measured by Bangladesh Atomic Energy Commission during November 1995 to January 1996 and detected 4.63 $\mu g/m^3$ of lead in ambient air over Dhaka [11], whereas, WHO standard for lead in air is 0.51 $\mu g/m^3$. A survey performed in 1997 by the Health Economic Unit of the Ministry of Health and Family Welfare indicated that the concentration of lead in blood samples of 39 people in Dhaka were well above the maximum tolerable limit of 10 $\mu g/dl$ recommended by WHO. The concentration levels ranged from a minimum of 13 $\mu g/dl$ to a 132 $\mu g/dl$. Besides government information, there are several independent research data available on instantaneous CO monitoring at Farmgate (11 ppm, 1 hour average), daily average NO_2 concentration (0.126 ppm) in selected urban intersections of Dhaka, PM_{10} (244.8 $\mu g/m^3$) and $PM_{2.5}$ (445.2 $\mu g/m^3$) measurements at Farmgate police box, DOE Agargaon office and rooftop of World Bank office, and volatile organic compounds (1,131 mg/m^3) measured at four locations. All the measured data exceed Bangladesh and/or international standards [11].

3.3 Sources and Mix of Pollution

Transportation system is the major contributor of emission in Dhaka. The relative emission of CO, HC, particulate matter, NO_x, and Pb by each modes of transportation system are estimated for the year 1999 under the study [11]. It has been computed that in the year 1999 a total of 86,311 ton of CO, 41,111 ton of HC, 11,497 ton of NO_x, 10,205 ton of PM, 3,614 ton of SO_2, and 69 ton of pb emitted from automobiles in Dhaka city [11]. Modal contribution of pollutant emissions are listed in Table –4.

3.4 Vehicle Emission Standards

Emissions from motor vehicles are regulated through new vehicle standards and in-use vehicle standards. The responsibility for setting vehicle standards rests usually with the national government. Imposing tighter vehicle emission standards does not usually result in direct additional costs for the government. Costs are usually passed on completely to vehicle owners. Governments can stimulate the purchase of cleaner vehicles by giving tax credits to buyers of vehicles that produce fewer emissions than the current emission standards, as has been successfully done in some European countries.

The European Union (EU) adopted catalyst-forcing standards for new gasoline-fuelled cars in the early 1990s (so called Euro 1 standards) and have gradually tightened them in several steps: Euro 2 in 1996, Euro 3 in 2000 and Euro 4 in 2005. Similar requirements were adopted for diesel cars and light and heavy commercial vehicles. In conjunction with the tightening of vehicle standards, fuel quality improvements were also mandated. In some cases, fuel modifications are necessary to allow the introduction of vehicle technologies that are required to meet the new vehicle emissions standards [1]. For example, the adoption of Euro 1 standards for gasoline vehicles requires the use of unleaded gasoline. The adoption of Euro 2 standards for diesel vehicles will require the use of diesel with sulfur levels lower than 500 parts per million (ppm). Further reductions in sulfur levels in both gasoline or petrol and diesel fuel are linked with Euro 3, 4 and for diesel trucks, Euro 5 standards (Table 1). In setting new vehicle standards, policymakers must appreciate the close linkage between vehicle standards and the resulting technologies and fuels requirements, and must assure that the appropriate fuel quality will be available when the vehicle standards are introduced.

3.5 Principles for Setting New Vehicle Standard

In setting new vehicle standards, policymakers should be guided by the following principles [1]:

- Those countries where the appropriate fuel is available can leapfrog to Euro 2, Euro 3 or Euro 4 standards quickly. Depending upon the seriousness of the air pollution problem, policymakers should strongly consider jumping forward to the most stringent standards possible after assuring that the appropriate fuel quality would be available.
- The implementation of new vehicle emissions standards will be facilitated if governments announce the schedule for tightening requirements well in advance. Policymakers should formulate short-term and long-term plans for adopting vehicle and fuel standards so that the vehicle and fuel industries have sufficient time to adapt.
- As a practical matter, the technology being built into cars and trucks to comply with the US, European and Japanese standards is very similar. Therefore, allowing compliance with any of these current requirements may be an efficient approach to standards setting for new vehicles for many countries, and should be considered by policymakers.
- The development of new vehicle standards will require active dialogue between the motor and oil industries to ensure that required fuels will be available. Policymakers should encourage such a dialogue.

- As new vehicle standards are tightened, in-use vehicle standards should also be tightened and these in turn should form the basis for routine vehicle inspections.

3.6 Fuel Selection

Over the course of the past 30 years, pollution control experts around the world have realized that cleaner fuel is a critical component of any effective clean air strategy [12]. In recent years, this understanding has strengthened and spread to most regions of the world. Fuel quality is now seen as not only necessary to reduce or eliminate certain pollutants directly (e.g., lead), but also as a precondition for the introduction of many important pollution control technologies (e.g., lead and sulfur). Further, one critical advantage of cleaner fuels has emerged—its rapid impact on both new and existing vehicles. For example, tighter new car standards can take ten or more years to be fully effective, whereas lowering lead levels in gasoline reduces lead emissions from all vehicles immediately.

3.7 Principles for Setting Fuel Quality Standards

In setting fuel quality standards, policymakers should be guided by the following general principles [12]:

- Implementing a successful systems approach to setting fuel standards requires institutional mechanisms that include a variety of stakeholders from government, private sector and civil society, and allows for extensive consultation. In countries where such an institutional mechanism is not yet in place, it should be created.

- Environmental and public health concerns are the driving force behind improvements in fuel quality, thus the Environment Department should have a major role in setting fuel standards.
- Department of Environment should develop a short and medium-term strategy that identifies standards to be adopted over the next several years, so as to allow fuel and the vehicle providers sufficient time to adapt.
- The main impediment to adopting state-of-the-art new vehicle emissions technology (equivalent to Euro 3 and 4) in Asia is fuel quality, especially lead and sulfur levels in gasoline and sulfur levels in diesel. These parameters should receive the highest priority in the development of medium- and long term strategies for fuel standards. Raising the necessary capital funds is the major issue in investing in new refinery units to manufacture low-sulfur diesel fuels.
- In developing fuel standards, countries should attempt to work closely with neighbouring countries and harmonize standards where possible. This should not, however, be used as an excuse for delaying or watering down requirements, as harmonization does not mean that all countries must follow the same time schedule.
- In order to implement stricter fuel standards and make associated costs more acceptable to consumers, countries should institute more and better awareness campaigns. Such campaigns must emphasize the public health consequences of not improving fuel quality.
- Subsidies that favour fuels which produce high emissions, should be eliminated; tax policies which encourage the use of the cleanest fuels,

should be adopted. Conventional fuel improvements should clearly distinguish between primary steps and secondary steps. The former includes removing lead from gasoline, dramatically reducing sulfur levels in gasoline and diesel, and the addition of detergent additives. The latter involves reducing the Reid vapour pressure and the benzene content in gasoline.

3.8 Fuel Quality

3.8.1 Gasoline **:** The pollutants of greatest concern from gasoline-fuelled vehicles are carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), lead, and certain toxic hydrocarbons such as benzene. Each of these can be influenced by the composition of gasoline used by the vehicle. The most important characteristics of gasoline with regard to its impact on emissions are lead content, sulfur concentration, volatility and benzene level.

3.8.2 Properties of Gasoline :

a. Lead additives: Lead does not exist naturally in gasoline but must be added to it. Since the early 1970s, however, there has been a steady movement toward reducing lead in gasoline and increasingly, the complete elimination of lead. Approximately 85% of all gasoline sold throughout the world is now unleaded. Table–2 shows the timing of lead phase out in different markets. All modern gasoline-fuelled vehicles being produced today can operate satisfactorily on unleaded fuel, and approximately 90% of these are equipped with a catalytic converters that require the exclusive use of lead-free fuel. There is no longer any doubt that lead is toxic and prevents the use of the clean gasoline vehicle technology that can dramatically reduce CO, HC and NOx emissions.

b. Sulphur : For cars without catalytic converters, the impact of sulfur on emissions is minimal. For catalyst-equipped cars, however, the impact on CO, HC and Nox emissions can be substantial. Based on the Auto/Oil study [12], it appears that NOx would decline about 3% per 100-ppm sulfur reduction for a typical catalyst-equipped car. The situation is even more critical for advanced low-pollution catalyst vehicles. Operation on gasoline containing 330-ppm sulfur will increase exhaust volatile organic compound (VOC) and Nox emissions from current and future new vehicles (on average) by 40% and 150% respectively, relative to their emissions with fuel containing roughly 30-ppm sulfur. In light of these impacts, it is not surprising that Japan has had typical gasoline sulfur levels under 30 ppm for many years. The US has adopted a 30-ppm sulfur limit and the European Union (EU) requires gasoline with a maximum sulfur content of no more than 50 ppm in 2005 when Euro 4 standards come into effect. Even more recently, the EU has proposed to limit sulfur levels to a maximum of 10 ppm. In Bangladesh, the sulphur limit is much (about 1000 ppm) higher than the above mentioned standard.

- In order to maximize the performance of current catalyst technology, gasoline sulfur concentrations should be reduced to a maximum of 500 ppm as soon as new vehicle standards requiring catalysts are introduced.

c. Vapour Pressure: Another important fuel parameter is vapour pressure. The vapour pressure for each season must be as low as possible in order to minimize evaporation from storage terminals and vehicles, but sufficiently high to give safe cold starts. An important advantage of gasoline volatility controls is that they can affect emissions from the gasoline distribution system and vehicles already in-use.

- Gasoline vapour pressure should be reduced to a maximum of 60 kilo Pascals whenever temperatures in excess of 20°C occur.

d. Other gasoline properties: According to the Auto/Oil study, "NOx emissions were lowered by reducing olefins, raised when T90 was reduced, and only marginally increased when aromatics were lowered." In general, reducing aromatics and T90, the temperature at which 90% of gasoline evaporates, caused statistically-significant reductions in exhaust mass non methane hydrocarbons (NMHC) and CO emissions. Reducing the olefins increased exhaust mass NMHC emissions, however "the ozone forming potential" of the total vehicle emissions was reduced. With regard to toxics, the reduction of aromatics from 45% to 20% caused a 42% reduction in benzene but a 23% increase in formaldehyde, a 20% increase in acetaldehyde and about a 10% increase in 1,3-Butadiene. Reducing olefins from 20% to 5% lowered 1,3-Butadiene by 31% but had insignificant impacts on other toxics. Lowering the T90 from 360 to 280^0 F resulted in statistically significant reductions in benzene, 1,3-Butadiene (37%), formaldehyde (27%) and acetaldehyde (23%).

- To the extent that the long-term vehicle emissions standards strategy is to adopt Euro 4 standards for light duty vehicles, the European gasoline standards (see Table 2) should be adopted in the same time frame.

Detergent or engine deposit control additives are critically important with modern engines and should be mandatory as well.

3.9 Vehicle Emission Standards For Bangladesh

The Vehicle Emission Standards (VES) deal with emissions from all kinds of petrol and diesel vehicles. California State Department of Public Health first adopted the emissions standards in 1959-60 limiting the exhaust of hydrocarbons and carbon monoxides for petrol engine vehicles. In 1963 a standard for diesel vehicle smoke emission was also established. Revised and more stringent standards were adopted in 1970. Soon after the implementation of US vehicle emission standards, various European countries started vehicle exhaust emission control program and formulated a standard namely ECE-15 Exhaust Emission Standard in 1970 [13]. In Asia, Japan became pioneer in 1966, establishing emission standard for medium and small gasoline cars and later they covered all kinds of motor vehicles. Bangladesh acted very slowly in understanding the benefits of implementing these standards. The government notified the first emission standard under the environment conservation rules in 1997. Current Bangladesh Vehicle Emission Standard is shown in Table – 5.

3.10 Limitations of Bangladesh VES (1997)

The 1997 standards are incomplete, have some inherent limitations and more importantly lack strategies for proper effective implementation. For this reason, no infrastructure or systems have been developed to ensure its compliance. Some of the inherent limitations both in terms of content and application are illustrated below [14] :

- The first obvious limitation is that vehicle types are not mentioned, e.g, motorcycles, cars, buses, and trucks.
- The standard for petrol and diesel vehicles are also not mentioned. Emission characteristics of these two types of vehicles are not the same. For example, in case of petrol engines, CO and HC are the criteria pollutants, whereas for diesel engine particulate matters (PM) and nitrogen oxides (NO_x) are the criteria pollutants.

- The 1997 VES lacks flexibility in terms of application, as no separate standards are considered for newly registered vehicles and the in-use vehicles.
- It is obvious that the 1997 VES is much more stringent in comparison to the emission level of the vehicles at that time. Generally vehicles in Bangladesh emit much more CO than the limit. The actual HC emissions is 10 –20 times the limit mentioned in the standard. Also pollution emission varies with make and types of vehicles.
- Generally vehicle emission standards start with lenient limits and then gradually reach the optimum level. The 1997 VES are too stringent and in some cases impracticable.
- Fuel quality significantly affects the pollution emissions from vehicles. But the present standard gives no guideline as to what should be the quality of commercial petrol or diesel fuel for better pollution emissions.
- Test procedure, inspection and enforcement program and the strategies for effective implementation are not laid down.

3.11 Principles For Setting New Revised VES (1997) of Bangladesh

Considering the above mentioned limitations of the present vehicle emission standards, a revised standard have been proposed, which will be implemented very shortly. In setting the new VES, following general principles were followed [14]:

- The concerned authority should set a lenient limit first, so that majority of the vehicles fall within that limit.

- The future standards should be elaborate mentioning each type of vehicle, separate standards for new and in-use vehicle and also specify the type and modality of emission inspection test.
- The standards should be enacted as a law, requiring all vehicle owners to comply with it. There may be a sticker system as a proof of fitness.
- The emission inspection and certification program should be simple, effective, totally objective and transparent.
- The responsibility for emission inspection test may be delegated to private institution under the government's effective and energetic supervision.

3.12 In-Service Vehicle Emission Test Program In Dhaka – (Data Analysis And Results)

Air Quality Management Project (AQMP) of the Department of Environment has undertaken a study to assess emission characteristics of the current vehicle population in Dhaka and recommend appropriate in-service vehicle emission standards that can be implemented as part of an inspection and maintenance (I&M) program. A survey to collect emission data from in-service petrol and diesel vehicles was carried out in Dhaka during June 2002 ~ January 2003 [15]. As more and more CNG auto-rickshaws are coming into the market, emissions from some of these vehicles were also measured. The idle emission test for CO and HC is being used in a large number of countries all over the world for in-service vehicle emission inspection due to its simplicity and low cost. Similarly , for the diesel vehicles, the "free/snap acceleration smoke test" is the most widely used inspection test method as there is no alternative low-cost, more efficient method available. In this program these inspection test method were employed. Emissions measurements from petrol and CNG vehicles were carried out at 9 different locations spread over the city . Diesel smoke emissions were measured in 4 BRTC depots and 7 roadside sites. The total number of vehicles tested for each category is shown in Table – 6.

3.13 Emission Data of In-Service Vehicles

The emission data were statistically analyzed for frequency and cumulative distribution. The percentages of vehicles satisfying different emission levels were estimated to provide information for establishing in-service vehicle emission standards [15].

3.13.1 Idle CO Emissions of Petrol and CNG Vehicles: The results of idle CO emission measurements for different categories of vehicles are summarized in Table – 7.

- About 65% of the petrol cars, taxis and other light duty vehicles gave idle CO emissions of less then 3.0% and 74% vehicles less then 4.5%. Post 1990 vehicles were observed to produce generally lower emissions than the older vehicles. However, the correlation between the CO emission and vehicle model year obtained through linear regression of the data was very poor (correlation coefficient , $R^2 = 0.105$).
- Motorcycles / scooters powered by both 2 and 4-stroke engines are in use. These are high emitters of CO. Only 22% motorcycles have CO below 4.5 and 59% vehicles below 7%.
- The 4-stroke petrol auto-rickshaws again are high emitters of CO as only about 38% gave CO below 4.5% and 54% below 7%. As much as one-third of these vehicles, had CO more than 9%.

- The CNG powered auto-rickshaws are very low emitters of CO . 90% of the vehicles tested had less than 1.0%. However, some of these vehicles were operating on petrol when tested and were found to be very high emitters of CO (average 6.7%).

3.13.2 Idle HC Emissions of Petrol and CNG Vehicles: The results of idle HC emission measurements for different categories of vehicles are summarized in the Table –8.

- About 75% cars / taxis and light duty vehicles had idle HC emissions of 600 ppm and more than 93% vehicles, 1200 ppm.
- There was very poor correlation between the vehicles model year and idle HC emissions, the correlation coefficient R^2 being only 0.04.
- Motorcycles with 4-stroke engines as expected had lower emissions than the 2-stroke motorcycles. More than half (53%) of the 2-stroke motorcycles have HC above 12,000 ppm.

However, 4-stroke motorcycles are also observed to be high emitters of HC when compared to cars. Only 39% of 4-stroke motorcycles are observed to have HC emissions below 1200 ppm, and 59% below 3000 ppm.

- 4-stroke engine petrol auto-rickshaws also gave significantly higher idle HC compared to cars. About 66% of these had HC more than 1200 ppm and 33% more than 3000 ppm.
- CNG operated three wheelers, as expected, gave quite low HC emissions, 88% falling below 600 ppm and almost all below 1200 ppm. From these vehicles most HC would be methane and therefore idle HC standards for these vehicles may not be necessary.

3.13.3 Combined Analysis of Idle CO and HC Emissions of Petrol and CNG Vehicles: The three categories of petrol / CNG vehicles (cars and light duty, auto-rickshaws and motorcycles) have significantly different emissions. In particular, auto-rickshaws and motorcycles have been found to have higher emissions than cars and light duty vehicles. Therefore, separate inspection standards are recommended for each category. Furthermore, 2-stroke motorcycles generate far greater levels of HC emissions than 4-stroke motorcycles. Therefore separate standards for 2-stroke and 4-stroke motorcycles are recommended. Both CO and HC standards must be satisfied for a vehicle to pass the inspection test. As stated, the standards are to be determined based on the collected data so that only the gross polluters are targeted. Therefore, the percentage of vehicles passing various levels of both CO and HC emissions has been calculated. The results are presented in Table—9 , 10 and 11.

3.14 Proposed In-Service Inspection Standard

As stated previously, the objective of the emission measurement program was to establish realistic and appropriate in-service vehicle emission standards for the Dhaka vehicle fleet. Initially cut-points were to be calculated for setting standards so that only approximately 20—30% of vehicles would fail [15]. However, measurements have shown that a large proportion of vehicles, particularly motorcycles, auto-rickshaws, trucks and light and medium duty diesel vehicles are gross polluters. Therefore, consistent with vehicular emission control objectives, standards for these vehicle categories have been recommended that will result in a higher failure rate.

It may be noted here that enforcement of these standards through periodic inspection will allow vehicle operators adequate time and opportunity to carry out necessary repairs to the gross polluting vehicles before submitting for inspection. During roadside inspection, a limited number of vehicles are to be tested every day and therefore the number of vehicles that fail roadside inspection each day is unlikely to generate adverse public reaction. Furthermore, this I&M program will be supplemented by public awareness and education campaigns to make vehicle operators aware of the program so that they can take appropriate action. The proposed standards are presented in Table—12.

3.15 Inspection , maintenance and other strategies to reduce emissions from in-use vehicles

Combustion-powered vehicles naturally tend to deteriorate with age and usage, and as a result, emission levels can rise significantly. Good maintenance is required to keep emissions levels at or near design levels. Such maintenance is not always performed or performed properly. Targeted inspection and maintenance (I&M) programs, however, can identify problem vehicles and assure their repair, thereby contributing substantially to lower emissions and improved air quality. So as not to overwhelm the service sector or create a strong political backlash, I&M stringency should be gradually phased in so that initially only the worst 15% to 20% of the vehicle fleet fails with periodic tightening of the in-use standards as the service industry and maintenance practices adapt. Centralized I&M systems (sometimes called "test only" systems) where the inspection function is separated from the maintenance function have consistently been found to be much more effective than decentralized systems, where inspections and repairs are combined. It is very difficult to supervise and audit test and repair systems and to prevent corruption and poor quality control. Policymakers must resist adoption of programs that combine testing with repair and that are very unlikely to achieve significant emissions reductions [16].

The shift towards a “loaded test” rather than the “idle test” currently used in most I&M systems in Asia will require new, additional test equipment including chassis dynamometers. The costs of such equipment will make it difficult for small-scale workshops to take part in the implementation of an I&M program, which is another reason for considering a centralized system. Experience from across the world has demonstrated that while governments should regulate I&M programs, the actual implementation of I&M programs is best carried out by the private sector, provided that there is competition in the market. Policymakers should assure an open and transparent bidding process. An adequate fee structure should be developed in which the affected vehicle owners pay the full costs of the I&M program including the costs of auditing and overseeing the private sector-run program by government or private auditors, and that will still allow private sector operators to make a sufficient profit to maintain, replace and upgrade equipment as required. Where multiple ministries (e.g., Environment, Police, Transport) or different levels of government (e.g., national and local) are involved in the I&M program, special care must be taken to assure that there is a full dialogue with all appropriate ministries or departments at the early stages of program design and that full agreement is worked out regarding specific roles and responsibilities. I&M programs typically also include testing for roadworthiness and safety. Departments and organizations responsible for this part of the I&M program need to be fully involved in the discussions on design and functioning of the I&M program. To strengthen the chances for success of I&M programs there must be a well-thought out public awareness program that explains the public health need for the program, the potential benefits and how the program works. A careful and thorough dialogue among all relevant stakeholders including providers, regulators, enforcers/police, vehicle manufacturers, the driving public and media must be facilitated at the earliest stages of program development and subsequently maintained throughout implementation. This needs to be coupled with an effective enforcement mechanism to assure motorist participation in the program. In countries where motor vehicle registration requirements are routinely and effectively enforced, registration-based I&M enforcement systems have been very effective. Quality assurance including covert and overt auditing and quality control should be properly planned and implemented. This will help to prevent, root out and penalize any corruption that has negatively impacted several I&M systems in Asia. Roadside testing can complement a more comprehensive motor vehicle inspection system but not replace it. Policymakers should ensure that roadside testing is designed as a complement to but not an alternative to testing in fixed stations. The roadside testing should primarily have the function of identifying gross polluting vehicles.

Some cities and countries have started, or are considering, using remote sensing devices to identify gross polluting vehicles. So far the effectiveness of such equipment in the Asian context has not been well-established. The quality and readability of number plates is often weak in Asian countries and only few countries in Asia have reliable computerized databases, which will make it possible to summon gross polluting vehicles.

In the Philippines, an innovative program was started in which mobile phones are used to identify gross polluting vehicles. The initial experience has been that on average in the first two months, 1,000 vehicles are reported on a daily basis.

Experience has demonstrated that it is important to have the required capacity in place to follow-up on initiatives that actively involve the public. While a great deal of attention has been paid to the "I" in I&M, it is the "M" that actually reduces emissions. Any I&M program needs to be accompanied by a program aimed at the maintenance and repair sector. I&M programs if operated properly will identify vehicles that do not comply with in-use emissions standards. Very often the quality of repairs is weak and needs attention. Careful attention must be paid to assuring that the service industry has sufficient lead time to properly equip itself to repair vehicles properly that are found to be not in compliance with tighter emissions standards. In addition, adequate training must be made available so that the mechanics and technicians are sufficiently skilled. As vehicles become more sophisticated the need for the service industry to retool and retrain becomes more important. Policymakers need to consider how to develop and implement effective programs for certification of workshops, technicians and spare parts. This will require an institutionalized dialogue with the auto and repair industry. In certain cases it will be not be feasible to reduce pollution through the introduction of tighter emissions standards and the only solution will be to scrap the vehicle, ban its entry in heavily polluted areas, or change the fuel type

CHAPTER – FOUR

TRAFFIC CONGESTION IN DHAKA CITY

4.1 Introduction

Mega city Dhaka, with about 10 million people encounters with innumerable constrains. The traffic congestion is one of the core problems in Dhaka city. The continuing expansion of traffic volume without any improvement of the road network system has made the traffic movement into a complex one. Probably Dhaka is one of the peculiar cities in the world where heterogeneous characteristics of traffic stream comprising slow speed and very high speed vehicles are observed on the same lane of the road. The evaluation of Dhaka's traffic system envisages that there are still many areas of improvement including road infrastructure, traffic management, public transportation, pedestrian, traffic safety and institutional development.

4.2 Present State of Dhaka City

The total number of population in Dhaka city is about 10 million. In 1974, this was 2.25 million, in 1981 it was 3.43 million recording an annual growth rate of 7.5% approximately. Available vehicles in Dhaka city are buses, trucks, rickshaws, pushcart, motorcycles, van, minibuses, taxis, auto rickshaws, bicycles etc. In most of the roads the main problems is the movement of rickshaws which results in traffic hazards.

4.2.1 Population State in Dhaka

The gradual growth of population in Dhaka city stated as [17];

- In 1951 the number was -- 0.336 million
- In 1961 the number was --- 0.540 "
- In 1974 the number was -- 1.68 "
- In 1981 the number was --- 3.46 "
- In 1984 the number was --- 4.20 "
- In 1996 the number was --- 8.80 "
- In 2000 the number was -- 10.00 "

4.2.2 Vehicle State

The year wise vehicles registered in the whole country and in Dhaka city are shown in the Table - 14 and 15 [18].

4.2.3 Road Network

Dhaka city has a very inadequate road network, which is only 8-10% of total city area, whereas acceptable ratio is 25%. Greater Dhaka has a total road network of approximately 2230 km of which 25% are primary roads. The width of the roads varies from 6-40m. The main roads are 15-25 m wide. Newly built roads are 40m wide, while the roads in old Dhaka are even less than 6m wide.

4.2.4 Road and Transport Availability : Comparison of road and road transportation in selected Asian cities [19] are shown in the Table – 16.

4.2.5 Vehicular Traffic Demand on Roads : Traffic congestion in Dhaka city is caused by high share of non-motorized vehicles, high share of auto rickshaws and the low share of road for bus. The road vehicular traffic composition on roads are shown in Table – 18 [20].

4.3 Reasons of Traffic Congestion in Dhaka City :

It is very hard to tell about the causes of congestion in Dhaka city as it does not follow any pattern. It is a common practice in Dhaka to blame rickshaws as the only reason for creating traffic congestion. But in reality there are several reasons behind this problem.

- ***Significant Increase in Population and Vehicles***: All the major export oriented industries, corporate offices, significant number of Export Promotion Zones, head offices of almost all multinational companies, higher educational facilities and even the major international airport of the country, are located in and around greater Dhaka city.

  Thus the city controls the economic development of the whole country. For these reasons, most of the rural-urban migration of Bangladesh is towards Dhaka city and it constitutes about 60% of Dhaka's increasing population. Dhaka, at present, is one of the most populous cities in the world. At present, greater Dhaka has about 10 million people. The city's urbanization rate is one of the highest in the world and it is projected that by the year of 2010, Dhaka will be the sixth largest city of the world with a population of 18 million. The increasing population obviously increases the demand for more vehicles on the streets. Also they can easily provide the necessary labour force, especially, for the informal sector. The more the traffic, the more will be the congestion, as the city has only a very limited infrastructure.

- ***Simultaneous Presence of Motorized and Non-motorized Vehicles on the Same Lane:*** In Dhaka city both motorized and non-motorized vehicles occupy the same streets at the same time. Their speeds are different, therefore almost all the time traffic congestion exists on the roads. Most of the rickshaw pullers, do not have any training and they are not even aware of the traffic rules.
- ***Traffic Mismanagement:*** Insufficient number of traffic police and traffic signals, flaws in traffic markings, violation of traffic rules and regulations etc can also be cited as some of the main reasons for traffic congestion in Dhaka city.
- ***Improper Implementation of Traffic Rules:*** People usually do not want to follow the traffic rules, as there is no proper implementation of these rules. Even though traffic police is usually present at every nodes of intersections, they do not do their duties properly. Traffic rules are also very flexible.
- ***Encroachment of Roads and Sidewalks:*** Street vendors, hawkers and street front shop owners occupy about 60% of the 163 km footpaths of Dhaka city. The sidewalks are also filled up by construction materials, garbage or even temporary houses of homeless people. Very often pedestrians are forced to walk on the main roads instead of using the sidewalk because of these reasons.

CHAPTER – FIVE

METHODOLOGY OF THE PRESENT WORK AND EXPERIMENTAL SETUP

5.1. Introduction

Traffic congestion always poses negative affect upon the society. It poses severe threat to economy as well as to the environment. In 1997, the annual economic wastage caused by traffic congestion was approximated at US $ 75 million. Since Dhaka has the largest share of the total vehicle of the entire country, congestion becomes a usual phenomenon in Dhaka. Numerous intersections add to the severity of congestions. About 20 congested intersections of Dhaka city were responsible for 75% of the total vehicle delays in 1997 [21].

This study determines the actual fuel consumption and emissions by different types of octane/petrol driven vehicles. The vehicles are driven on three pre-selected routes and actual consumption and emissions are measured. Three routes are selected considering the types of flow, main entry to commercial district, number of intersections, connection with commercial and business areas, number of rail crossings etc.

5.2 Methodology

There are several methods to measure the tailpipe emissions of carbon monoxide (CO), carbon dioxide (CO_2) and hydrocarbon (HC). The easiest and familiar method is 'the On-board measurement system', but this system is very expensive and also not available in our country. For collection of on-road data of vehicle emissions and to get the real-world result, an alternative method has been followed in this study. The description of the instrument used for the alternative method is given below.

5.2.1 Crypton CMT (CUDOS Modular Trolley): The Crypton CMT is the latest development in the CUDOS garage equipment range. As the name implies it is a highly modular product that can be used in any combination of engine analyzer, system tester, emission analyzer, wheel aligner and it can also be used as a technical terminal for the display of advanced CD-ROM based vehicle information, parts catalogues and workshop control functions. A range of external measurement modules and software application programmes enable the powerful computer to be personalized for particular applications. The modules are connected to the host computer via high speed RS232 communication links. The computer is a specially selected PC compatible unit built to meet the demands of the workshop environment, without compromising the ability to accept the full range of PC compatible accessories.

The engine test application programme gives the Crypton computer system the personality of an advanced computer engine analyzer. The engine test programme and other programs are permanently stored on the hard disk, thus removing the need to insert and remove different disks. Flexibility of operation is the keynote, coupled with the ability to display a wealth of engine information either by component-dedicated readings or digitised waveforms. A range of setting and repair petrol vehicle data disks (SRDs) provide all the data required to enable the application software to make accurate diagnoses. An engine analyzer module (EAM) forms a major part of the applications kit. The EAM is a remotely mounted measurement module which processes the engine signals and enables connection to the engine under test. Processes information is sent by serial link to the computer, when requested by the host software, which further manipulates this information to provide the test display and diagnosis information on the VDU.

5.2.2 Emission Analyser 290 EN2

This is one of the components of Crypton CMT- 2100. This HI-spec analyser is a fully microprocessor controlled exhaust gas analyzer employing non-dispersive infra-red (NDIR) techniques. The unit measures CO, CO_2 and HC. By providing further channel employing electro- chemical measurement of O_2. Zero and gas calibration may be commanded at any time by the operator, and automatically executed by the analyzer. An automatic auto zero check is performed every 30 minutes when the analyzer is switched on.

Figure-5.1 Crypton CMT Emission analyzer 290 EN2

5.3 Connections to vehicle

***5.3.1 Sample probe*:** Sample probe are inserted into the vehicle exhaust noting that it is not necessary to insert the whole length of the flexible section. Care must be taken not to allow the flexible steel probe end to be kinked. An adjustable clip is used to secure the probe to the tail pipe. Care must also be taken not to force the probe into the exhaust. Some vehicles have very short tail pipe sections and it is possible to damage the probe and the exhaust itself. Care should be taken to remove the probe from the exhaust at the end of the test. The sample pipe should not be rolled up whilst it is still connected to the analyzer as excessive amount of water may enter the filter unit.

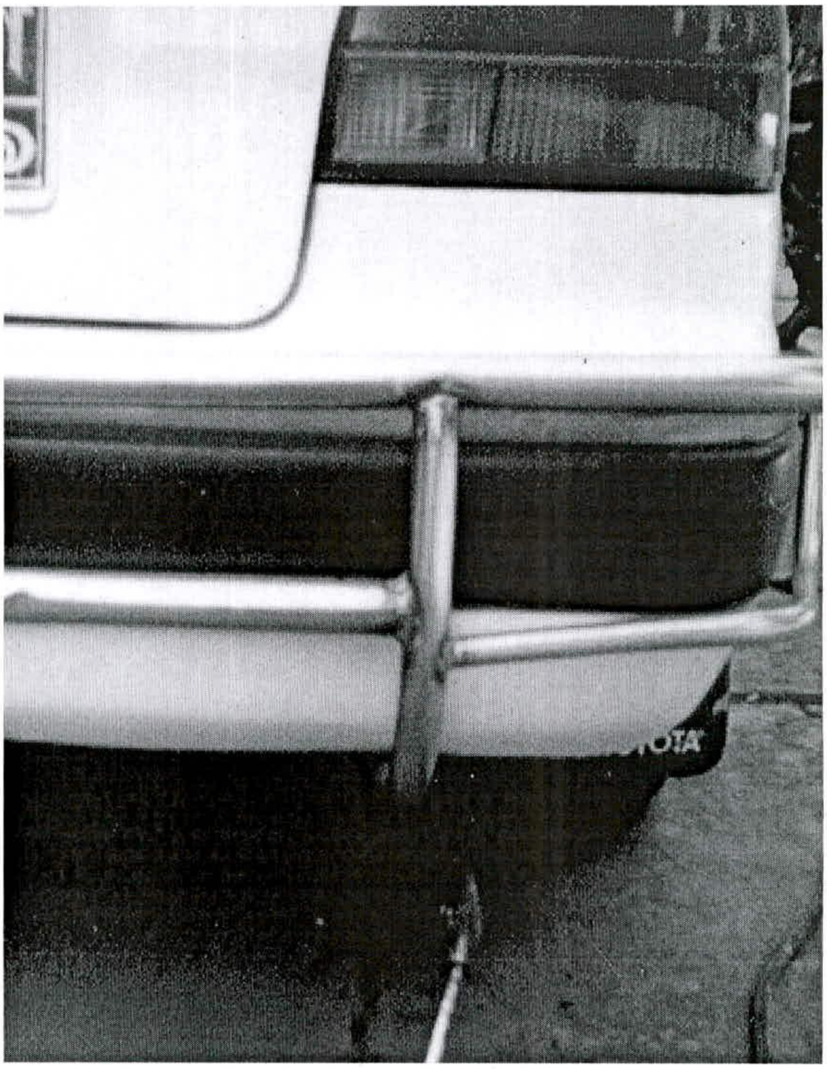


Figure-5.2 Sampling probe routed from vehicle tailpipe into vehicle.

***5.3.2 Oil Temperature Probe*:** After removing the dipstick from the engine, oil level should be checked. Compare the temperature probe to the dipstick and adjust the rubber bung so that the length of probe inserted into the engine is 10 – 15 mm shorter than that of the dipstick. There must, therefore, be sufficient oil to reach the probe. The probe should be inserted into the engine via the dipstick hole. The oil temperature will be displayed on the host equipment during carburator/injection test modes in steps of one degree.

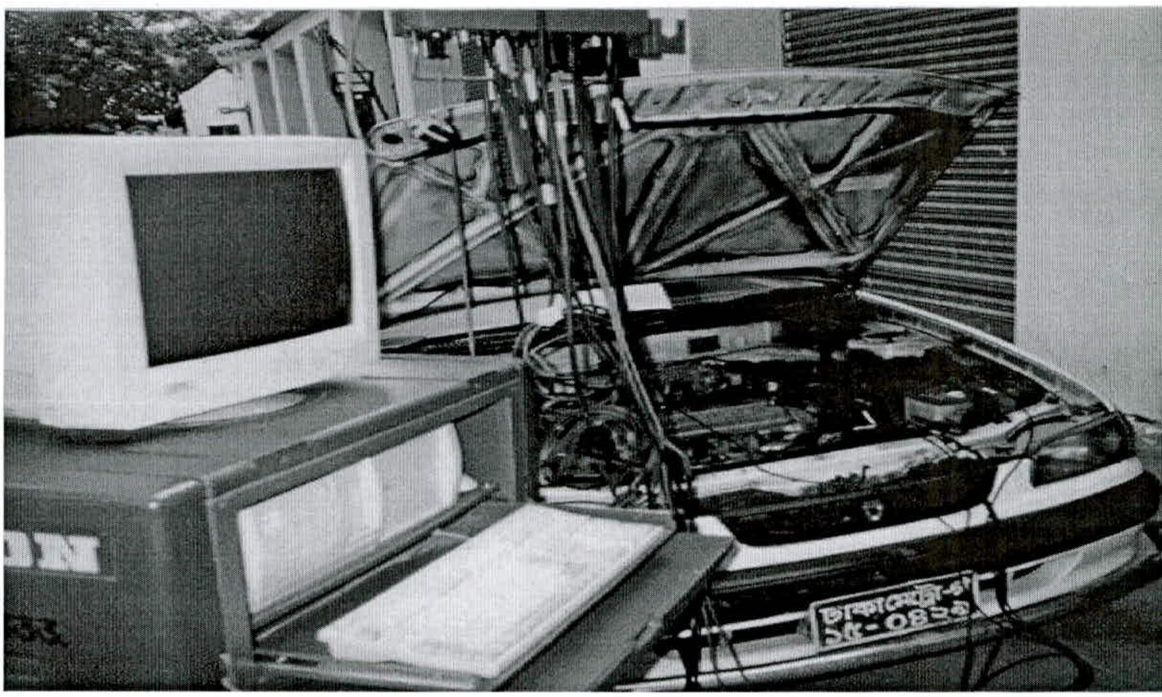


Figure-5.3 Connection of different data cables of analyzer 290 EN2 with the vehicle.

***5.3.3 Tachometer Probe*:** The digital tachometer is inbuilt with the equipment. The tachometer probe is attached to one of the HT leads, taking care to ensure that the lead is kept clear of all moving and excessively hot (e.g. exhaust manifold) parts in the engine. The engine speed will be displayed on the reading screens.

***5.3.4 Obtaining Correct Measurement Results*:** To ensure that the exhaust gas results are correct, it is vital that the following points are noted while performing the test.

a. Before testing a vehicle ensure that :
    - The engine oil is up to normal operating temperature.
    - There are no leaks in the exhaust system.
    - The CMT-290 is set for the correct fuel type for the vehicle under test, this ensures that the lambda calculation is accurate.
    - The exhaust sample probe is fully inserted.
    - The CMT-290 is set for the vehicle ignition system so that engine speed is correctly displayed, and check that the engine is running at the required speed.

b. The CMT-290 will automatically perform an auto zero whilst warming up, and at intervals during use. Any internal errors will also be indicated and halted.

c. The analyzer will display error message if faults are detected. These error messages fall into two categories ;
    - Messages such as 'failed leak test' and 'poor gas flow' can normally be fixed by the operator.
    - Error message that indicate an internal fault can only be fixed by an authorized service agent. The screen will explain the particular error.

d. The measured results are presented on the screen and do not normally need any interpretation. Provided that the correct fuel type is selected, the lambda calculation will be true. The engine should be run in a stable state for at least 20 seconds to allow gas readings to stabilize before results are recorded or printed.

e. Specific usage conditions are as follows ;
   - Main supply voltage 100 to 250 volts, 50/60Hz
   - Ambient temperature range $+5^0$ C to + 40^0 C
   - CMT-290 should not be used in rain or snow.

f. The CMT-290 can only be used with defined add on accessories if it is to be used for legislative exhaust gas emission tests. These include the oil temperature probe, the rpm pick-up and a printer.

5.4 Technical Specifications

The technical specifications of the Crypton CMT –2100 Emission Analyzer EN2 is given in Appendix –B [22].

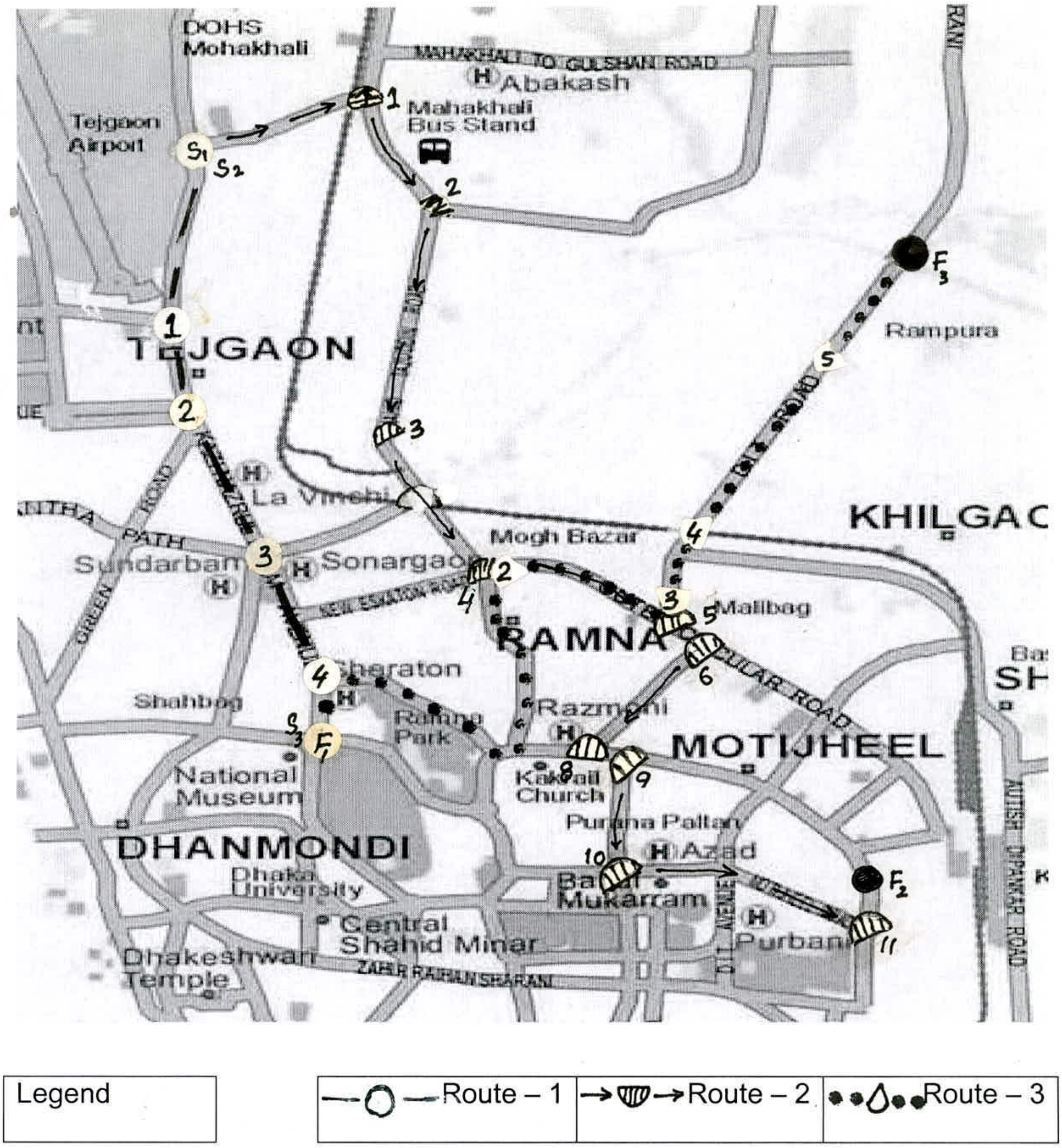
5.5 Selection of Routes

For the present study, three routes have been selected at the center of Dhaka city, considering the types of traffic flows, length of routes, number of intersections, the incidence of buildups along the route, location of business centers beside the routes, number of rail crossings, location of commercial areas etc have been taken into account. Route no.-1 (*Jahangir gate-Farm gate-Shahbagh*) is considered as the VIP road where only motorized vehicles are allowed to flow. The number of intersections on this route is five and distance is 4.3 km. Route no.-2 (*Jahangirgate–Mohakhali–Moghbazar-Malibagh-Kakrail-Bijoynagor-Palton-Dainikbagla-Shapla chattor)* flows through the main commercial area of Dhaka city, three major business centers are located besides this route.

Both motorized and non-motorized vehicles are allowed to ply on this route. The distance of this route is 9.2 km. Route no-3 *(Shahbagh-Seraton-Mintu Road-Moghbazar-Mouchak-Rampurabazar-TV Bhaban)* flows through the residential areas as well as three major business centers are located besides this route. The distance of this route is 5.8 km. Along the 3.5 km stretch of this route starting from TV Bhaban, non-motorized vehicles are allowed to ply on the roads while the rest is for motorized vehicles only. The details of three routes are given in Table 5.1 and also Figures 5.4 and 5.5.

Table-5.1 Details of three routes at the center of Dhaka city.

	Route No. 1	**Route No. 2**	**Route No. 3**
Route	Jahangir Gate- Farm Gate- Shahbagh	Jahangir Gate- Mohakhali- Moghbazar-Malibagh- Kakrail- Bijoynagar-Palton- Dainik Bangla-Shapla chattor	Shabagh-Seraton- Minturoad- Moghbazar- Mouchak-Rampura TV Bhaban
Length (km)	4.3	9.2	5.8
Number of Intersection	5	11	5
Types of Flows	Only motorized Vehicles	All types (Motorized and Non-motorized vehicle)	Mixed (some portion only motorized)



R O U T E	Intersections										
	1	2	3	4	5	6	7	8	9	10	11
1	Bijoy Swaranee	Farm-gate	SAARC fountain	Bangla-motor	Seraton	–	–	–	–	–	–
2	Moha-ghali	Gulsion Crossing	Shat-rashta	Mogh bazar	Mouchak	Mali-bagh	Santi nagar	Kakrail	Bijoy nagor	Palton	Shapla Chattor
3	Shera-ton	Mogh-Bazar	Mou-chak	Rail-Crossing	Rampura-Bazar	–	–	–	–	–	–

Figure-5.4 Selected different routes for experiment

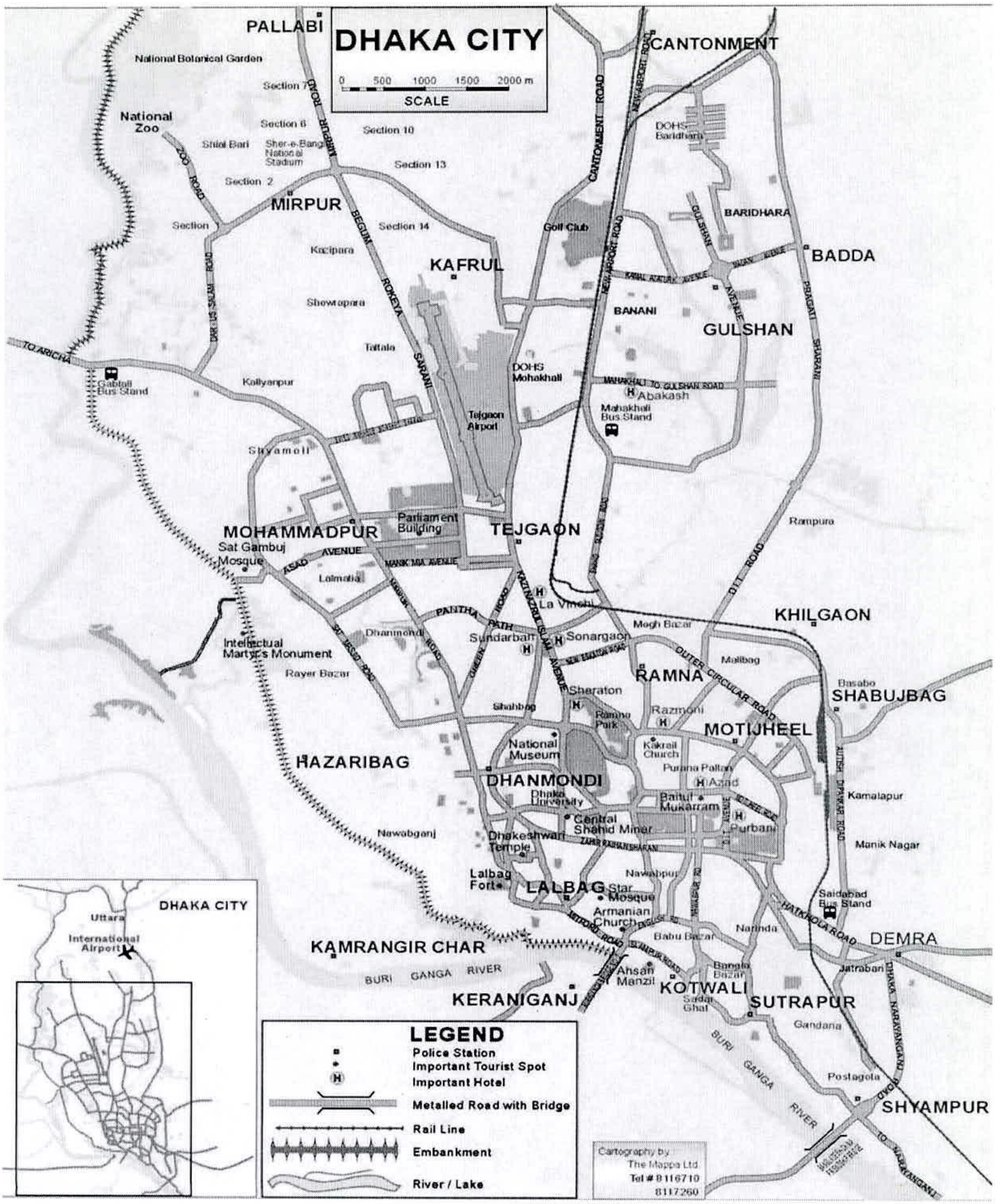


Figure- 5.5 Central Dhaka city map.

5.6 Tested Vehicles

A total six of vehicles of different models (EFI and carburetor operated engine) under different engine conditions have been tested for the three specified routes. The vehicle details are shown in Table –5.2 below.

Table –5.2 Details of the tested vehicles.

Sl/No	Tested Vehicle	Fuel	CC-Class	Mileage (km)
1	Vehicle no.-1	Octane (EFI engine)	1.3i (KAT)	55,342
2	Vehicle no.-2	Octane (EFI engine)	1.5 (AT)	1,24,517
3	Vehicle no.-3	Octane (Carburetor engine)	1.3 (AT)	1,23,036
4	Vehicle no.-4	Octane (Carburetor engine)	1.6i (KAT)	93,233
5	Vehicle no.-5	Octane (Carburetor engine)	1.3 (AT)	85,764
6	Vehicle no.-6	Octane (EFI engine)	1.5 (AT)	37,658

5.7 Travel Times : The selected vehicles have been driven during various traffic conditions; viz; morning peak hour (0830 hrs – 0930 hrs), evening peak hour (1630 hrs – 1730 hrs) and off– peak situation at noon (1230 hrs – 1330 hrs).

5.8 Experimental Procedure

The experiments are carried out in the following sequence :

5.8.1 Driving Vehicles: Out of the six vehicles, three of them have been driven both the way on each route at least three times for each travel times (morning, noon and evening). Continuous monitoring of speed of the vehicles for every 5 km/hr interval have been monitored and recorded manually. The data for these vehicles for each route at each travel time, the stoppage time and moving time of the vehicle at different speed interval have been calculated. These average timing is considered for all six tested vehicles, as illustrated in Table 19A.

***5.8.2 Stop Time at Intersections*:** Driving characteristics shows that almost half of the total travel time of the vehicles were in idle speed at the intersections. The average stop time of the vehicles at different routes are shown in tables below.

Table- 5.3 Average stop time at different intersections of the tested vehicles for route no-1.

Sl/No	**Intersection**	**Stop Time (sec)**		
		Morning	*Noon*	*Evening*
1	***Bijoy Swaranee***	90	30	80
2	***Farm Gate***	30	15	30
3	***SAARC Fountain***	390	120	320
4	***Bangla Motor***	75	30	65
5	***Seraton***	255	90	240
6	***Total Stopped Time***	**840**	**285**	**735**

Table –5.4 Average stop time at different intersections of the tested vehicles of route no-2.

Sl/no	Intersections	Stop Time (sec)		
		Morning (0900 hrs)	*Noon (1245 hrs)*	*Evening (1645 hrs)*
1	***Mohakhali***	420	65	480
2	***Gulshan Crossing***	260	60	345
3	***Shatrashta***	180	30	120
4	***Moghbazar***	620	240	580
5	***Mouchak***	1320	580	1370
6	***Malibagh***	480	120	240
7	***Santinagor***	300	65	265
8	***Kakrail***	210	30	180
9	***Bijoy Nagor***	180	45	150
10	***Palton***	480	180	420
11	***Dainik Bangla***	300	120	320
	Total Stopped Time	**4750**	**1535**	**4470**

Table – 5.5 Average stop time at different intersections of the tested vehicles for route no- 3.

Sl/no	Intersection	Stop Time (sec)		
		Morning	*Noon*	*Evening*
1	***Sheraton***	120	90	160
2	***Moghbazar***	240	120	210
3	***Mouchak***	1280	460	1340
4	***Mouchak Rail crossing***	210	90	240
5	***Rampurabazar***	260	80	210
	Total Stopped Time	***2110***	***840***	***2160***

Comparison between total travel time and stop time at different intersections of three routes at different traffic conditions are shown in figures below.

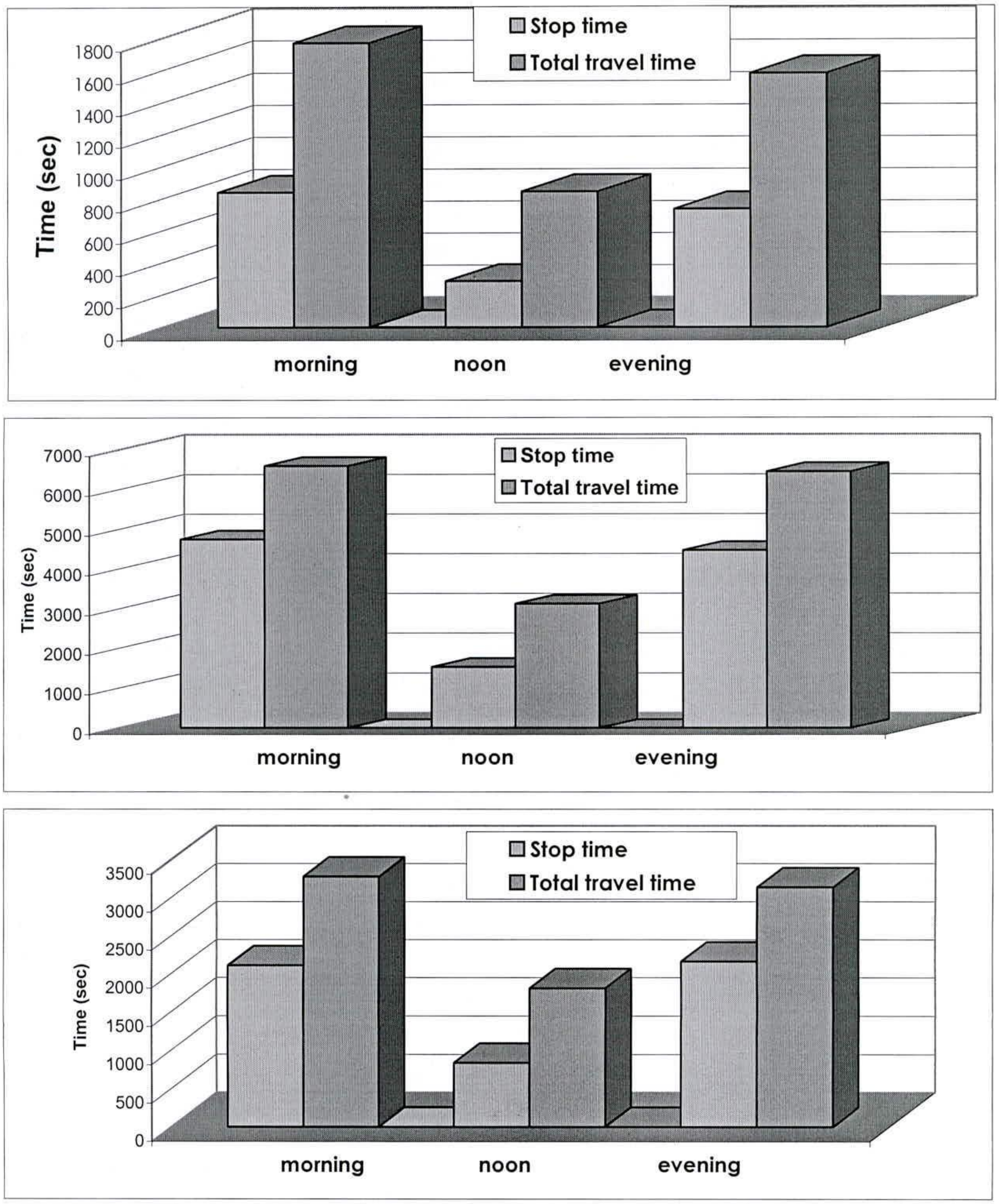


Figure 5.6 Comparison between total travel time and stop time of different routes at different intersection.

***5.8.3 Recording of characteristic data*:** The exhaust gas of the different types of vehicles, those were driven on the three different routes at three different traffic conditions, are investigated by the Crypton CMT Emission Analyzer EN2. The investigations/measurements were carried out by simulating the speed as those vehicles were run on the three specified routes. The characteristics data for six tested vehicles driven on the three specified routes at three different traffic times are shown in Appendix- C.

CHAPTER – SIX

RESULTS AND DISCUSSIONS

6.1 Introduction

A total six of vehicles of different models of different engine conditions were driven on the three specified routes of Dhaka city. Emissions from all these vehicles were determined/simulated by using an exhaust gas analyzer 'Crypton CMT Emission Analyzer 290 EN2' and fuel consumptions were measured by an indirect method. The results obtained from these studies are discussed in the following sections.

6.2 Measurement of Fuel Consumptions

According to the engine cylinder volume, the six tested vehicles are categorized into three groups. These are Cat-A (1331 cc), Cat-B (1551cc) and Cat-C (1621cc). One vehicle from each category was taken for measurement of fuel consumption in each route at three different traffic conditions. These vehicles were driven both the ways on each route at different traffic conditions at least three times. The total fuel consumption on each route at three different traffic conditions for both the ways was measured. The difference of consumed fuel measured for various categories of vehicles was not very significant, therefore the average fuel consumption to travel the different routes for all three categories of vehicles are considered same for all the tested vehicles. The total fuel consumptions by the three different category of vehicles are shown in Table 6.1.

Table – 6.1 Average fuel consumptions of the tested vehicles to travel different routes at different traffic conditions.

Routes	Distance (km)	Consumptions of fuel (litre)		
		Morning peak (0900 hrs)	*Noon normal (1245 hrs)*	*Evening peak (1645 hrs)*
Route – 1	*4.3*	0.708	0.338	0.632
Route – 2	*9.2*	2.638	1.252	2.580
Route - 3	*5.8*	1.312	0.724	1.256

The results show that the fuel consumption for route-1 at three traffic conditions (morning peak, evening peak and noon off-peak) are 0.708, 0.632 and 0.338 litres respectively. That for route-2 and route-3 are 2.638, 2.580, 1.252 and 1.312, 1.256, 0.724 litres respectively. The difference of fuel consumption in percentage (%) between morning and evening peak with noon off-peak for route-1 are 52.25% and 46.5%. For route-2 are 42.19% and 44.81% and for route-3 are 44.81% and 42.35% respectively.

Fuel economy, in kilometer per litre for the tested vehicles at different routes on different traffic conditions is shown in Figure below. It shows that in each three routes the fuel economy at peak hour is well below the usual consumption.

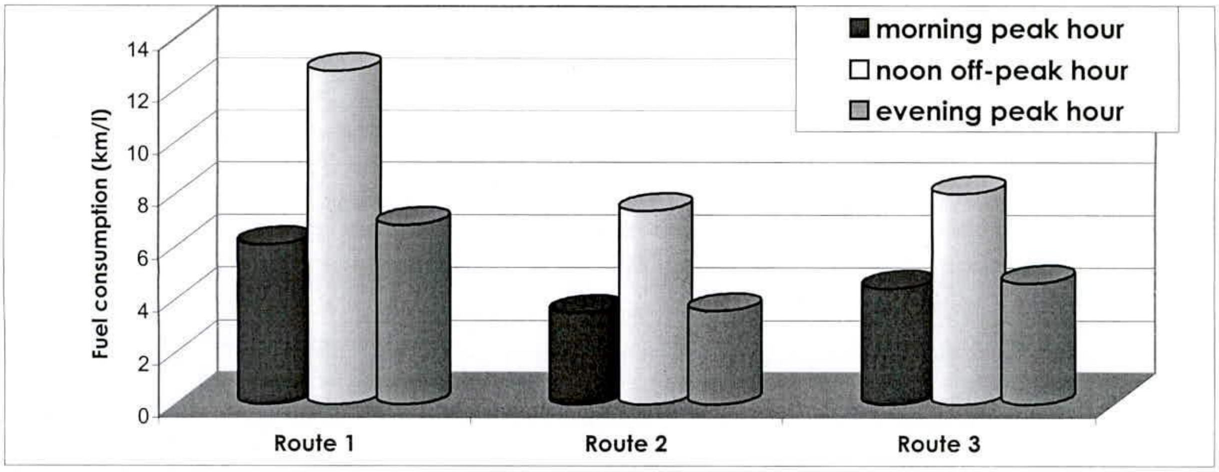


Figure 6.1 Average Fuel economy (km/l) of the tested vehicles on different routes at different traffic condition.

Normally, the fuel consumption (in litres/hr) at 15-20 km/hr is more than that at 35 km/hr. Even, if we assume that the fuel consumption is almost the same at 35 km/hr and at a speed less than that, a car on average runs twice as much fuel during the noon-normal hour and more than four times as much fuel during the morning and evening peak hours.

Likewise, emissions from cars are also doubled or quadrupled during off-peak and peak hours respectively.

6.3 Measurement of Travel Times

To get the total time required to travel three routes at different traffic conditions (morning and evening peak and noon off-peak), the tested vehicles have been driven both the way on each routes at least three times for each traffic conditions. Speed of the vehicles with respect to time for 5 km/hr interval have been continuously monitored and recorded manually. Measured travel time at different speed for different routes are shown in Table 19A. The time frequency at different speed for three routes at different traffic conditions are shown in Figures 6.2, 6.3 and 6.4.

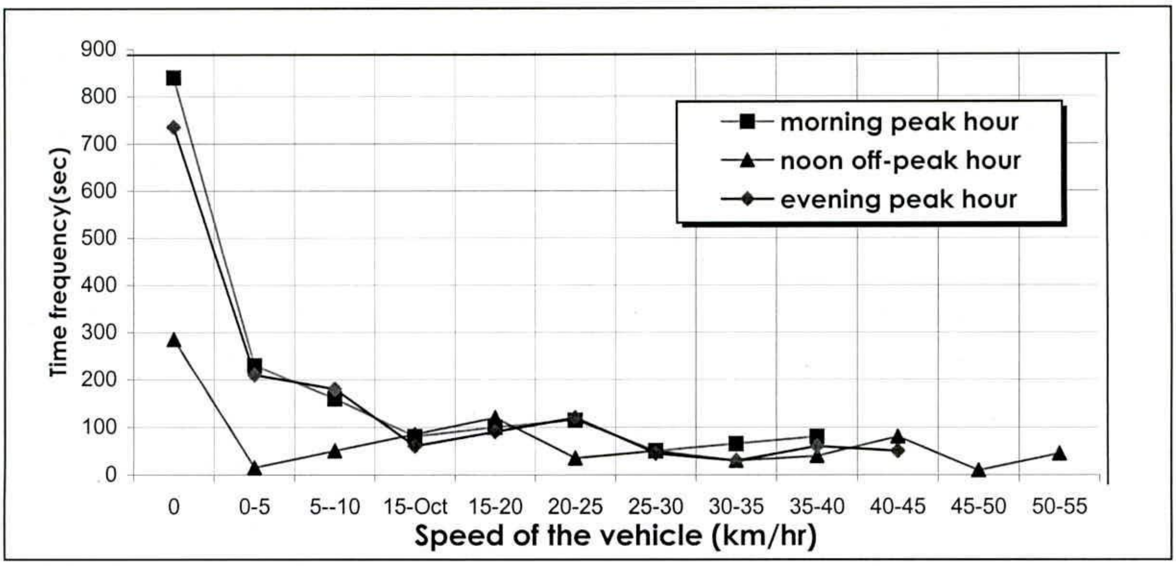


Figure 6.2 Travel time measured at different speed for route no –1.

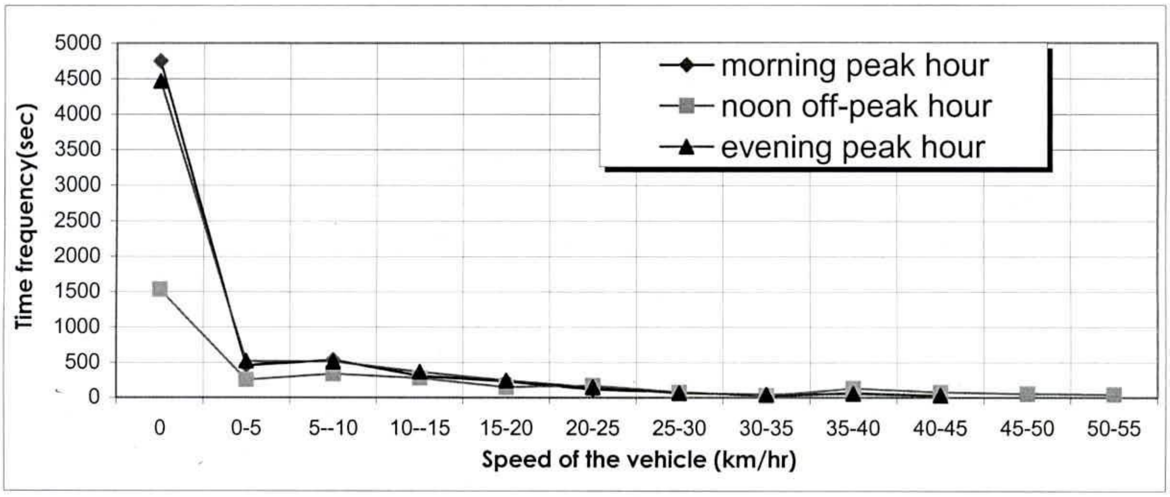


Figure 6.3 Travel time measured at different speed for route no –2.

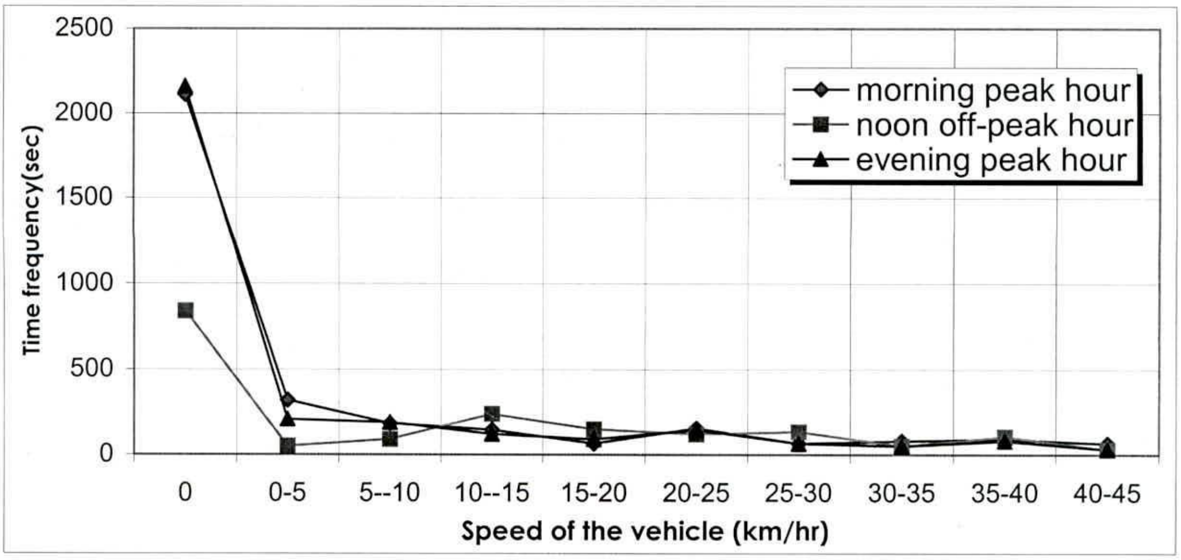


Figure 6.4 Travel time measured at different speed for route no –3.

6.4 Speed of the vehicles

The measured and calculated average speed of the tested vehicles on different routes at different traffic conditions are shown in Table - 6.2 and Figure 6.5.

Table – 6.2 Average speed of the tested vehicles on different routes at different traffic conditions.

Routes	*Distance* (km)	*Time required travel the distance (secs)*			*Average Speed of the vehicles (km/hr)*		
		Morning peak	Noon normal	Evening peak	Morning peak	Noon normal	Evening peak
1	*4.3*	1770	845	1580	8.75	18.31	9.80
2	*9.2*	6595	3130	6450	5.02	17.28	5.13
3	*5.8*	3280	1810	3140	6.36	11.54	6.65

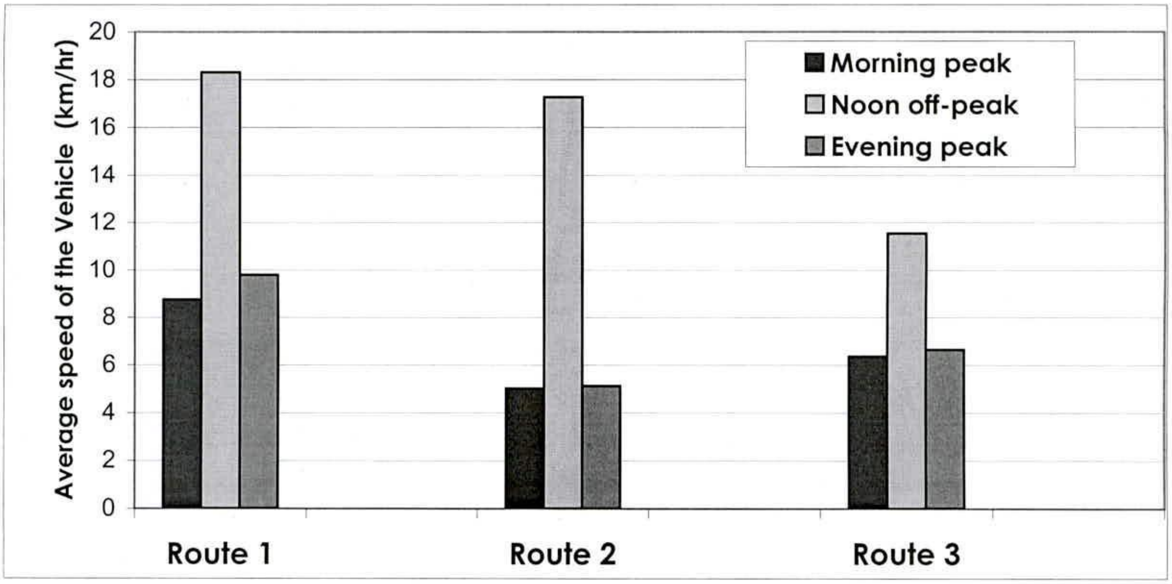


Figure 6.5 Average speed of the tested vehicles for different time *on different routes.*

The engine speed was recorded online for each test run by an on-board data acquisition system. These data were averaged over 30 seconds time period. Thus, the road speed of the vehicle was simulated from the measured engine rpm while taking emission data by the analyzer.

Table 6.2 and Figure 6.5 show that the average speed of the tested vehicles for route-1 at different traffic conditions (morning peak, noon off-peak and evening peak) are 8.75km/hr, 18.31 km/hr, 9.8 km/hr; that for route-2 are 5.02 km/hr, 17.28 km/hr, 5.134 km/hr and for route-3 are 6.36 km/hr, 11.54 km/hr and 6.65 km/hr respectively. The average speed of the vehicles in urban area is usually considered to be 35 km/hr [21]. The result thus shows the severity of traffic congestion in Dhaka city.

Meenar [21] shows that each lane of main roads in Dhaka city can bear a maximum traffic volume of 900 vehicles/hr, but traffic volume at Mouchak intersection is on the average 2749 vehicles/hr, at Kakrail 3898 vehicles/hr and at Khilgoan 1923 vehicles/hr [10]. These data clearly indicates the over congestion of traffic volume in Dhaka city, therefore the average speed of the vehicles are found far below than that of the normal speed.

6.5 Investigation of Exhaust Gas Emissions

Although the exhaust gas pollutant contains CO, NO_x, SO_2 and unburned HC this investigation is concentrated to identify quantitatively the percentage of CO and CO_2 and ppm of HC level of exhaust gas from gasoline engine vehicles. The analyzer used for this study did not have any facilities for measuring NO_x, and SO_2. Moreover, in a gasoline engine, the percentage of NOx and SO_2 is limited. In fact, a diesel engine vehicle emits NO_x remarkably more than a gasoline engine due to high temperature inside combustion chamber caused by high compression ratio. The components CO, CO_2 and HC contribute much to atmospheric pollution. The measured/investigated characteristics data of two vehicles (each from EFI and Carburetor operated engine) for route no–1 at different traffic conditions are shown in Tables –6.3 to 6.8

Table – 6.3 Measured characteristics data of vehicle no. –1 (EFI engine) driven on route no. –1 at morning peak (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	840	0.19	12.3	387	15.1	0.336	0.0227	0.34399	366.8	0.697	45.113	0.142
0–5	907	230	0.19	12.3	413	14.6	0.092	0.0062	0.09106	97.3	0.185	11.969	0.040
5–10	1087	160	0.67	12.4	382	14.4	0.064	0.0043	0.06248	66.8	0.448	8.286	0.026
10-15	1378	80	0.41	12.6	285	14.6	0.032	0.0021	0.03167	33.8	0.139	4.265	0.010
15-20	1554	100	0.39	12.9	253	14.6	0.040	0.0027	0.03959	42.3	0.165	5.458	0.011
20-25	1842	115	0.59	13.0	252	14.7	0.046	0.0031	0.04584	49.0	0.289	6.365	0.012
25-30	2029	50	0.45	13.1	315	14.5	0.020	0.0013	0.01966	21.0	0.095	2.753	0.007
30-35	2289	65	0.35	12.9	332	14.4	0.026	0.0017	0.02538	27.1	0.095	3.502	0.009
35-40	2429	80	0.34	12.8	325	14.2	0.032	0.0021	0.03080	33.0	0.112	4.221	0.011
40-45	2643	50	0.35	12.8	282	13.9	0.020	0.0013	0.01884	20.2	0.070	2.586	0.006
		1770					**0.708**	**0.0480**			**2.295**	**94.518**	**0.272**

Table– 6.4 Measured characteristics data of vehicle no. –1 (EFI engine) driven on route no. –1 at noon off-peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	285	0.19	12.3	387	15.1	0.114	0.0087	0.11671	124.4	0.236	15.306	0.048
0–5	907	15	0.19	12.3	413	14.6	0.006	0.0004	0.00593	6.3	0.012	0.781	0.003
5–10	1087	50	0.67	12.4	382	14.4	0.02	0.0014	0.01952	20.9	0.140	2.589	0.008
10-15	1378	85	0.41	12.6	285	14.6	0.034	0.0023	0.03365	36.0	0.147	4.531	0.010
15-20	1554	120	0.39	12.9	253	14.6	0.048	0.0033	0.04751	50.8	0.198	6.549	0.013
20-25	1842	35	0.59	13.0	252	14.7	0.014	0.0009	0.01395	14.9	0.088	1.937	0.004
25-30	2029	50	0.45	13.1	315	14.5	0.02	0.0014	0.01966	21.0	0.095	2.753	0.007
30-35	2289	30	0.35	12.9	332	14.4	0.012	0.0008	0.01171	12.5	0.044	1.616	0.004
35-40	2429	40	0.34	12.8	325	14.2	0.016	0.0011	0.01540	16.5	0.056	2.111	0.005
40-45	2643	80	0.35	12.8	282	13.9	0.032	0.0022	0.03015	32.3	0.113	4.138	0.009
45-50	2845	10	0.35	12.8	276	13.4	0.004	0.0003	0.00363	3.9	0.014	0.500	0.001
50-55	3049	45	0.35	12.8	247	12.8	0.018	0.0012	0.01562	16.8	0.059	2.156	0.004
		845					***0.338***	**0.0229**			**1.202**	**44.967**	**0.116**

Table – 6.5 Measured characteristics data of vehicle no. –1 (EFI engine) driven on route no. –1 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	858	840	4.05	10.7	1063	14.0	0.336	0.0227	0.31893	341.7	13.839	36.563	0.363
0–5	1027	230	3.95	10.6	1329	14.0	0.092	0.0062	0.08732	93.6	3.696	9.918	0.124
5–10	1231	160	4.39	10.3	1401	13.7	0.064	0.0043	0.05944	63.8	2.800	6.570	0.089
10-15	1554	80	6.78	9.0	1460	12.6	0.032	0.0021	0.02733	29.5	2.001	2.656	0.043
15-20	1728	100	7.21	9.2	1181	12.2	0.04	0.0027	0.03308	35.8	2.581	3.293	0.042
20-25	2198	115	6.94	9.0	1304	12.4	0.046	0.0031	0.03867	41.8	2.900	3.761	0.054
25-30	2454	50	7.10	9.1	1245	12.4	0.020	0.0013	0.01681	18.2	1.290	1.654	0.023
30-35	2691	65	7.32	9.0	1146	12.2	0.026	0.0017	0.02150	23.3	1.703	2.094	0.027
35-40	2790	80	7.50	9.0	1103	12.1	0.032	0.0021	0.02625	28.4	2.132	2.558	0.031
40-45	2889	50	7.93	9.0	1049	12.0	0.02	0.0013	0.01627	17.6	1.398	1.587	0.018
		1770					**0.708**	**0.0480**			**34.340**	**70.653**	**0.816**

Table – 6.6 Measured characteristics data of vehicle no. –3 (Carburetor engine) driven on the route no. –1 at morning peak hours (0900 hrs).

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	735	0.19	12.3	387	15.1	0.294	0.0199	0.3010	320.9	0.610	39.474	0.124
0–5	907	210	0.19	12.3	413	14.6	0.084	0.0057	0.0832	88.8	0.169	10.928	0.037
5–10	1087	180	0.67	12.4	382	14.4	0.072	0.0049	0.0703	75.2	0.504	9.322	0.029
10-15	1378	60	0.41	12.6	285	14.6	0.024	0.0016	0.0238	25.4	0.104	3.198	0.007
15-20	1554	90	0.39	12.9	253	14.6	0.036	0.0024	0.0356	38.1	0.148	4.912	0.010
20-25	1842	120	0.59	13.0	252	14.7	0.048	0.0033	0.0478	51.1	0.301	6.642	0.013
25-30	2029	45	0.45	13.1	315	14.5	0.018	0.0012	0.0177	18.9	0.085	2.478	0.006
30-35	2289	30	0.35	12.9	332	14.4	0.012	0.0008	0.0117	12.5	0.044	1.616	0.004
35-40	2429	60	0.34	12.8	325	14.2	0.024	0.0016	0.0231	24.7	0.084	3.166	0.008
40-45	2643	50	0.35	12.8	282	13.9	0.02	0.0014	0.0188	20.2	0.071	2.586	0.006
		1580					**0.632**	**0.0429**			**2.120**	**84.322**	**0.243**

Table – 6.7 Measured characteristics data of vehicle no. –3 (Carburetor engine) driven on the route no. –1 at noon off-peak hours (1245 hrs).

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	735	4.05	10.7	1063	14	0.294	0.0199	0.2791	299.0	12.109	31.993	0.318
0–5	907	210	3.95	10.6	1329	14	0.084	0.0056	0.0797	85.4	3.374	9.055	0.114
5–10	1087	180	4.39	10.3	1401	13.7	0.072	0.0048	0.0669	71.8	3.150	7.391	0.101
10-15	1378	60	6.78	9.0	1460	12.6	0.024	0.0016	0.0205	22.1	1.500	1.992	0.032
15-20	1554	90	7.21	9.2	1181	12.2	0.036	0.0024	0.0298	32.2	2.323	2.964	0.038
20-25	1842	120	6.94	9.0	1304	12.4	0.048	0.0032	0.0404	43.6	3.026	3.925	0.057
25-30	2029	45	7.10	9.1	1245	12.4	0.018	0.0012	0.0151	16.4	1.161	1.488	0.020
30-35	2289	30	7.32	9.0	1146	12.2	0.012	0.0008	0.0099	10.7	0.786	0.967	0.012
35-40	2429	60	7.50	9.0	1103	12.1	0.024	0.0016	0.0197	21.3	1.599	1.918	0.024
40-45	2643	50	7.93	9.0	1049	12	0.020	0.0013	0.0163	17.6	0.001	1.587	0.018
		1580					**0.632**	**0.0428**			**29.031**	**63.280**	**0.734**

Table – 6.8 Measured characteristics data of vehicle no. –3 (Carburetor engine) driven on the route no. –1 at evening peak hours (1645 hrs).

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	858	285	4.05	10.7	1063	14.0	0.114	0.0077	0.1082	115.9	4.695	12.405	0.123
0–5	1027	15	3.95	10.6	1329	14.0	0.006	0.0004	0.0057	6.1	0.241	0.647	0.008
5–10	1231	50	4.39	10.3	1401	13.7	0.020	0.0013	0.0186	19.9	0.875	2.053	0.028
10-15	1554	85	6.78	9.0	1460	12.6	0.034	0.0023	0.0290	31.4	2.126	2.822	0.046
15-20	1728	120	7.21	9.2	1181	12.2	0.048	0.0032	0.0397	43.0	3.097	3.952	0.051
20-25	2198	35	6.94	9.0	1304	12.4	0.014	0.0009	0.0118	12.7	0.883	1.145	0.017
25-30	2454	50	7.10	9.1	1245	12.4	0.020	0.0013	0.0168	18.2	1.290	1.654	0.023
30-35	2691	30	7.32	9.0	1146	12.2	0.012	0.0008	0.0099	10.7	0.786	0.967	0.012
35-40	2790	40	7.50	9.0	1103	12.1	0.016	0.0010	0.0131	14.2	1.066	1.279	0.016
40-45	2889	80	7.93	9.0	1049	12.0	0.032	0.0021	0.0260	28.2	2.237	2.538	0.030
45-50	3012	55	7.90	9.0	1040	12.0	0.022	0.0014	0.0179	19.4	1.532	1.745	0.020
		845					**0.338**	**0.0229**			**18.828**	**31.206**	**0.373**

The percentage of CO and CO_2, ppm of HC and AFR at different speed have been recorded by the emission analyzer at a simulated speed of the tested vehicles. The amount of measured emitted gas (CO, CO_2 and HC) by the two types of vehicles (EFI and Carburetor engine) at different routes on different traffic conditions is shown in Table –6.9.

Table –6.9 Difference of measured emitted exhaust gas in % between morning and evening peak hour with noon off-peak hour for vehicle no.-1 (* EFI engine *) and vehicle no.-3 (*Carbureted engine*)

VEHICLE-1	Route	*Travel Time(hrs)*	*Measured Emitted exhaust gas*			*Difference in % between morning & evening peak with normal noon*		
			CO (gm)	*CO_2 (gm)*	*HC (gm)*	*CO (%)*	*CO_2 (%)*	*HC (%)*
	1	0900	2.294	94.52	0.272	*47.6*	*52.4*	*57.35*
		1245	1.202	44.967	0.116	-	-	-
		1645	3.913	84.322	0.243	*43.3*	*46.67*	*52.26*
	2	0900	7.331	352.67	1.081	*51.59*	*52.73*	*56.05*
		1245	4.182	166.69	0.475	-	-	-
		1645	7.262	344.85	1.039	*42.42*	*51.66*	*54.28*
	3	0900	3.731	175.41	0.522	*33.74*	*44.61*	*49.42*
		1245	2.472	97.18	0.264	-	-	-
		1645	3.563	168.15	0.501	*30.62*	*42.21*	*47.31*

VEHICLE-3	Route	Travel Time(hrs)	Measured Emitted exhaust gas			Difference in % between morning & evening peak with normal noon		
			CO (gm)	CO_2 (gm)	HC (gm)	CO (%)	CO_2 (%)	HC (%)
	1	0900	5.223	106.03	0.206	50.97	52.18	60.68
		1245	2.561	50.706	0.081	-	-	-
		1645	4.688	94.621	0.184	45.37	46.41	55.98
	2	0900	17.891	394.76	0.916	48.61	52.51	60.04
		1245	9.195	187.52	0.366	-	-	-
		1645	17.638	386.11	0.883	47.79	51.43	58.55
	3	0900	9.141	196.48	0.431	41.72	44.75	53.36
		1245	5.327	108.56	0.201	-	-	-
		1645	8.622	188.06	0.421	38.22	42.53	52.26

The table also shows the difference of emissions in percentage between peak and off-peak hour. It shows that the emission at peak hour is about 45% more than that of off-peak hour by the EFI engine vehicles. For the Carburetor operated engine vehicles the difference is higher. The average emissions of CO and HC in gm/km and gm/hr of the tested vehicles in different routes at different traffic conditions are shown in Figures 6.5 to 6.8.

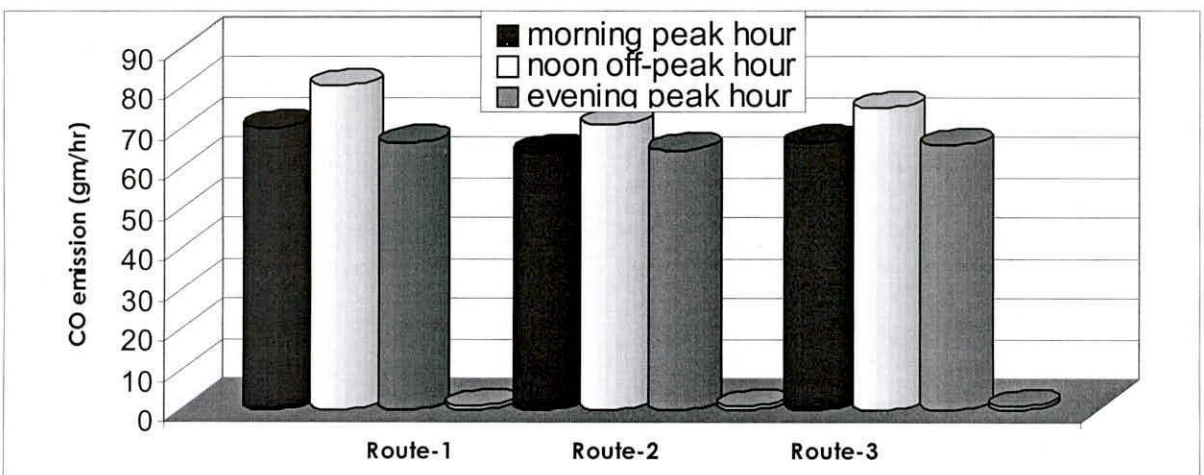


Figure-6.6 Average CO emission (gm/hr) of the tested vehicles in different routes at different traffic condition.

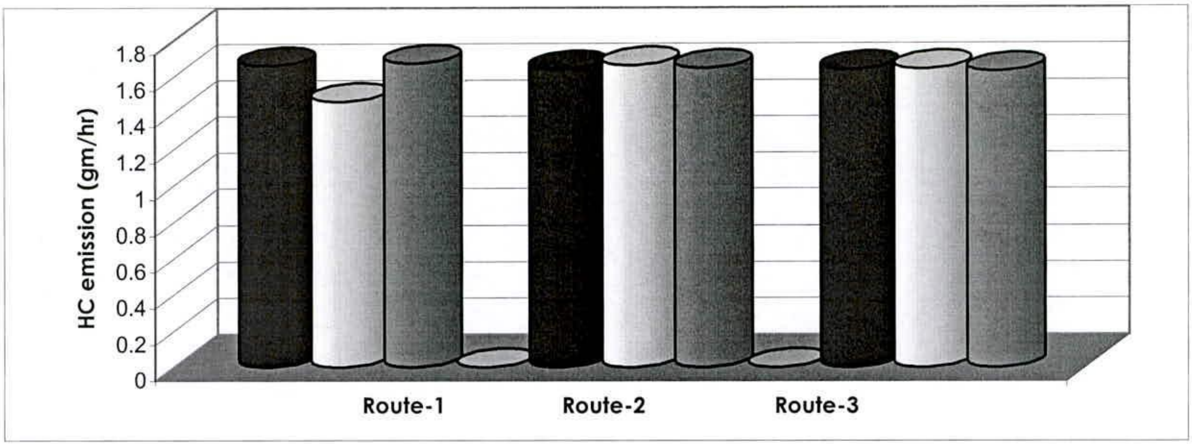


Figure-6.7 Average HC emission (gm/hr) of the tested vehicles in different routes at different traffic condition.

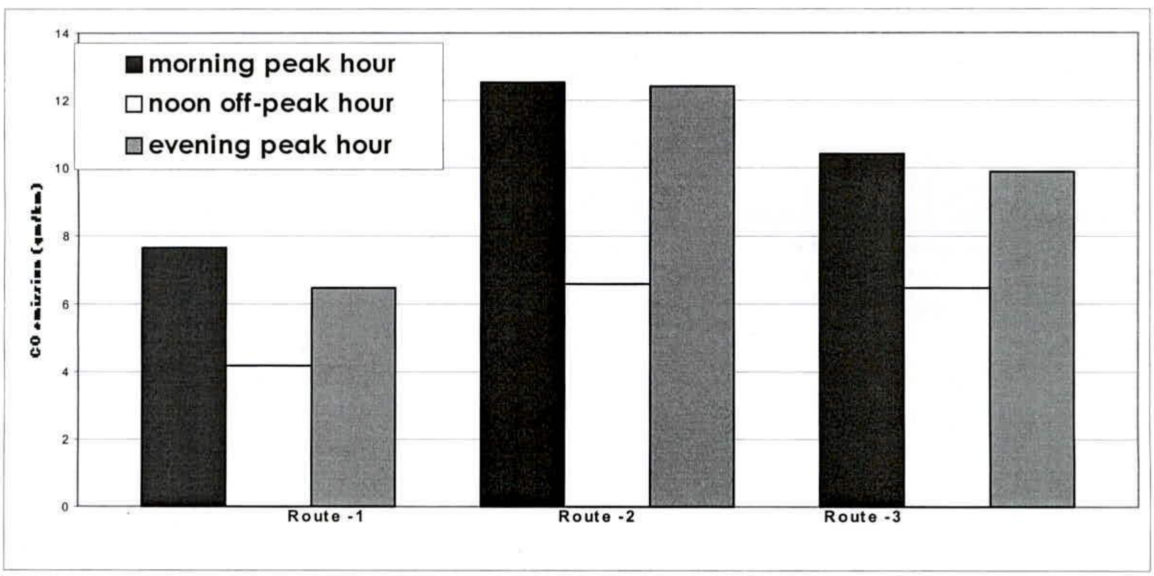


Figure-6.8 Average CO emission (gm/km) of the tested vehicles in different routes at different traffic condition.

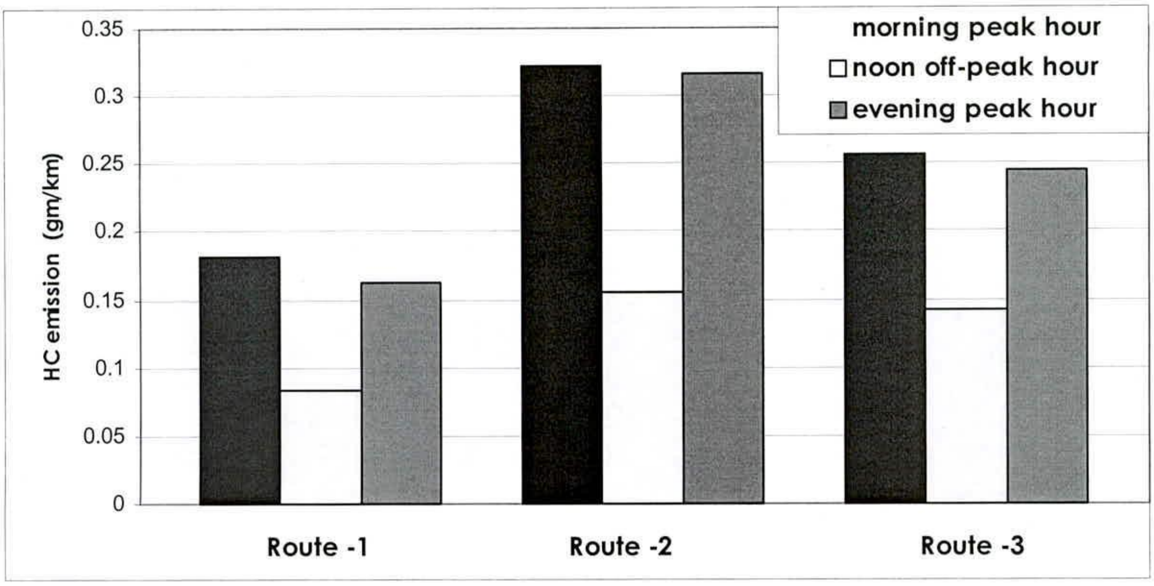


Figure-6.9 Average HC emission (gm/km) of the tested vehicles in different routes at different traffic condition.

Figure 6.7 show that the emission of CO (gm/km) at peak hour in route-2 is about 66% and 22% more than that of route-1 and route –3 respectively. This happens because the motorized and non-motorized vehicles flows simultaneously on route no-2, therefore the stoppage time is comparatively more than that of route no.-1. Same thing happens for HC emission which is shown in Figure 6.4.

Data shows that the stoppage time is less and the average speed of the tested vehicles are more at noon (off peak-hour) as compared to the morning and evening (peak-hour), as such the amount of pollutants also less at noon (off peak-hour).

Data also show that all the emitted exhaust gases (CO, CO_2 and HC) are about 50% higher at morning and evening peak hours than that in noon off-peak hour. Though the average speed of the vehicles at noon off-peak traffic hour is well below the average speed (35 km/hr) of the vehicles in urban areas.

CHAPTER – SEVEN

CONCLUSIONS

The measurements have shown that the fuel consumption in Dhaka city is very high. In the rush hour the fuel consumption of passenger cars went above 28 litres per 100 kilometers. Although consumption was 42% to 53% higher in the rush hour than in normal flowing traffic, even the normal flowing speed is well below the usual vehicle speed. The same conclusions can be made for the exhaust gas emission.

The results of findings from the present work may lead to conclude the following:

- The average speed of vehicles on different routes are very low compared to the standard urban speed.
- The average speed of the vehicles at the peak hour is about half that of noon normal traffic time.
- About a half of the total travel time consumed as a stoppage time at different intersections.
- Fuel consumptions on different routes are much higher than that of normal consumptions.
- Fuel consumption at morning and evening rush hour on the same route on the same day is about two times than that of noon normal traffic time.
- The amount of pollutant emissions are much higher than the set standard.
- The heterogeneous characteristics of traffic stream on the same route make the average speed of the vehicles well below the normal speed thus causes the higher amount of emission.

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APPENDIX - A

TABLES

Table – 1A European Standards for Gasoline and Diesel Fuel that Coincide with Gasoline and Diesel-Fuelled Vehicle Standards [1]

	Gasoline		Diesel
Standard	***Lead***	***Sulfur (ppm)***	***Sulfur (ppm)***
Euro 1	0	NA	NA
Euro 2	0	500	500
Euro 3	0	150	350
Euro 4	0	50_a	50_a
Euro 5_b	NA	NA	50_b

a *10 ppm is in the late stages of adoption by the European Union*
b *Heavy Duty Diesel Engines only*

Table 2A Phase Out of Lead in Gasoline from Different Markets [2]

1970	1980	1990	2000
* 1973 United States[a]	* 1980 Japan	* 1996 Thailand[b]	* 2000 India
	* Thailand[a]	* 1996 United States[b]	* 2000 China
	* 1985 Malaysia[a]	* 1998 Malaysia[a]	* 2000 Taiwan
		* 1998 Singapore	* 2001 Vietnam
		* 1999 Bangladesh	* 2001 Philippines
		* 1999 Hongkong	* 2001 Indonesia
		* 1999 Nepal	* 2002 Sri Lanka
			* 2002 Pakistan

[a] Gradual phase out
[b] Nationwide ban

Table - 3A Gasoline Specifications in Asia and Europe [12]

	Lead	*Sulfur ppm*	*Benzene % v/v max*	*Aromatics %*	*Olefins %*	*Oxygen % m/m max*	*RVP Summerk pa,max*
Linked to Euro-3 vehicle standard Effective 2000	Lead free	150	1.0	42	18	2.7	60
Linked to Euro-4 vehicle standard effective 2005	Lead free	50	1.0	35	18	2.7	60
Bangladesh	Lead free	1000	-	-	-	-	0.7 kg/m^2
India	Lead Free	1000[a]	5[b]	-	-	2.7	35-60
Japan	Lead Free	100	1.0	-	-	-	78
Singapore	Lead Free	-	-	-	-	-	-
Srilanka	Lead Free	1000	4.0	45	-	2.7	35-60

[a] *In Delhi, Mumbai, Kolkata and Chennai sulfur levels are 500 ppm*
[b] *Benzene – 3% in metros and 1% in National Capital Region*

Table - 4A Model Contribution of Pollutant Emissions [11]

Pollutant Emission	*Truck and Tanker (t/yr)*	*2-stroke Engine (t/yr)*	*Car and Jeep (t/yr)*	*Bus and Minibus (t/yr)*	*Motorcycle (t/yr)*
CO	4,440 *(5%)*	32,178 *(37%)*	26,465 *(31%)*	2,481 *(3%)*	20,746 *(24%)*
HC	2,664 *(6%)*	23,019 *(56%)*	3,605 *(9%)*	1,249 *(3%)*	10,574 *(26%)*
NO_x	5,209 *(45%)*	639 *(6%)*	2,262 *(20%)*	3,019 *(26%)*	367 *(3%)*
PM	4,151 *(40.6%)*	47 *(0.5%)*	1,281 *(12.5%)*	4,708 *(46.1%)*	18 *(0.2%)*
SO_2	1,776 (49%)	38 (1%)	139 (4%)	1,629 (45%)	33 (1%)
pb	0	28 *(41%)*	21 *(30%)*	0	20 *(29%)*

Table - 5A Current Bangladesh Vehicle Emission Standard (Environment Conservation Rules, 1997 [15]

Parameter	*Unit*	*Standard Value*
Hydrocarbons (HC)	**g/km**	**2**
	Volumetric	**180 ppm**
Oxides of Nitrogen (NO_x)	**g/km**	**2**
	Volumetric	**600 ppm**
Carbon Monoxides (CO)	**g/km**	**24**
	Volumetric	**4%**
Black Smoke*	**Hartrige Smoke Unit (HSU)**	**65**

* *Measured at 2/3 of maximum rotating speed*

Table - 6A Category-wise Number of Tested Petrol/CNG/diesel Vehicle [15]

Vehicle Types	*Number of Vehicle Tested*
Petrol Vehicles (Idle CO and Emission measured)	
Passenger car	**515**
Taxi	**102**
Microbus/van	**114**
Auto-rickshaw (4 stoke Petrol)	**34**
Motor Cycles	**91**
Jeep/pick up	**166**
Total Petrol Vehicles	***1022***
Petrol Vehicles (Idle CO and emission measured)	
Passenger car	**18**
Taxi	**22**
Microbus/van	**5**
Jeep/Pick up	**1**
Auto-rickshaw (4 stoke CNG)	**59**
Total CNG Vehicles	***105***
Diesel Vehicles (Free acceleration smoke opacity measured)	
Double Taker bus	**141**
Single decker and mini bus	**169**
Trucks	**105**
Light and medium duty vehicles	**88**
Total Diesel Vehicles	***503***

Table - 7A Percentage of Vehicles Below Different Idle CO Emission Levels [15]

Idle CO %	Cars/Taxis other Light Vehicles			Motorcycle	Auto-rickshaw (4 stroke Petrol)
	Pre-1991 Model	*1991 and Later models*	*All*		
3	37	75	65	12	33
4	42	81	71	20	36
4.5	47	83	74	22	38
5	52	86	77	32	41
6	60	89	81	44	45
7	70	92	86	59	54
8	77	95	90	79	60
9	86	97	93	88	66

Table - 8A Percentage of Vehicles Below Different Idle HC Emission Level [15]

Idle HC, ppm	Cars/Taxis and Light Vehicle	Motorcycle		Petrol Auto-rickshaw (4-Stroke)	CNG Auto-rickshaw
		2-Stroke	*4-Stroke*		
400	*58*	*0*	*5*	*10*	*80*
600	*75*	*0*	*13*	*14*	*88*
800	*83*	*0*	*28*	*25*	*92*
1000	*90*	*0*	*35*	*31*	*93*
1200	*93*	*0*	*39*	*34*	*98*
2000	*97*	*0*	*48*	*57*	*100*
3000	*99*	*1*	*59*	*67*	*100*
4000	*99*	*3*	*63*	*71*	*100*
5000	*99*	*5*	*68*	*79*	*100*
6000	*100*	*8*	*68*	*79*	*100*
8000	*100*	*21*	*70*	*88*	*100*
10000	*100*	*30*	*73*	*95*	*100*
12000	*100*	*47*	*78*	*97*	*100*

Table - 9A Percentage of Cars and Other Light Duty Vehicles Below Different Idle CO and HC Levels [15]

Idle HC ppm	Percent Vehicles		
	4.0% Idle CO	***4.5% Idle CO[a]***	***5.0% Idle CO***
600	64	66	68
800	67	69	71
1,000	69	72	75
1,200[a]	70	73[a]	76
1,500	71	74	77

[a] *Proposed in service vehicle emission standard*

Table - 10A Percentage of Petrol Auto-rickshaws Below Different Idle CO and HC Levels [15]

Idle HC ppm	Percent Vehicles		
	7.0% Idle CO[a]	***8.0% Idle CO***	***9.0% Idle CO***
1,000	25	29	29
1,200	26	31	32
1,500	34	38	42
2,000	41	45	48
3,000[a]	44[a]	48	52
4,000	45	49	54
5,000	48	54	64

[a] *Proposed in-service vehicle emission standard*

Table – 11A Percentage of 2-Stroke Engine Motorcycles Below Different Idle CO and HC Levels [15]

Idle HC ppm	Percent Vehicles		
	7.0% Idle CO[a]	*8.0% Idle CO*	*9.0% Idle CO*
8,000	14	16	18
10,000	20	25	27
12,000[a]	37[a]	41	44
15,000	52	59	62

[a] *Proposed in-service vehicle emission standard*

Table - 12A Proposed in-service Vehicle Emission Standard for Dhaka [15]

Sl no	Vehicle Type	Pollutant	Test Method	Limit
1	*Passenger Cars and Other Light and Medium Duty Petrol/CNG Vehicles*	*CO*	*Normal Idle*	4.5%
		HC	*Normal Idle*	1,200 ppm
2	*Auto-rickshaws Petrol*	*CO*	*Normal Idle*	7%
		HC	*Normal Idle*	3,000 ppm
3	*Auto-rickshaws, CNG*	*CO*	*Normal Idle*	1%
4	*Motorcyles (2-stroke and 4-stroke)*	*CO*	*Normal Idle*	7%
		HC	*Normal Idle*	12,000 ppm
		HC	*Normal Idle*	3,000 ppm
5	*Diesel Vehicles*	*Smoke*	*Free acceleration*	$3.2m^{-1}$ or 75 HSU

Table – 13A Adverse Health and Environment Effects of Vehicle Emission [4]

	Health Effect					**Climate Change**	
Pollutants	***Direct***	***Indirect***	***Acid***	***Eutrophication***	***Visibility***	***Direct***	***Indirect***
CO	x						
HC	x	x[a]					x
NO_x	x	x[a]	x	x	x	x	x
PM	x				x	x	
SO_x	x		x		x		x

[a] *Ozone*

Table - 14A Number of Year Wise Registered Motor Vehicles in Bangladesh [18]

Types of vehicles	Before 1995	1995	1996	1997	1998	1999	2000	2001	2002	Total
Motor car	51,312	8,714	12,478	8,354	5,876	4,986	4,087	6,587	6,757	**1,09,151**
Jeep/Station Wagon/Micorbus	27,460	2,451	2,408	1,459	2,705	2,269	1,517	3,068	3,782	**47,119**
Taxi	1,908	28	59	14	103	216	580	771	2233	**5912**
Bus	27,510	214	149	99	286	267	237	594	740	**30,196**
Minibus	24,007	1,085	795	866	602	479	404	1,218	2,314	**31,770**
Truck	27,919	3,787	3,164	1,282	2,733	2,018	2,725	2,575	2,377	**48,580**
Auto rickshaws/Tempo	35,586	14,953	11,984	6,546	4,403	2,140	3,135	397	5,479	**84,623**
Motorcyle	1,63,699	11,389	13,977	12,080	14,525	16,511	14,614	24,409	29,047	**3,00,251**
Others	5,872	1,383	1,443	1,583	1,248	2,617	1,365	2,491	2,148	**20,550**
Total =	**3,35,071**	**44,004**	**46,858**	**32,583**	**32,481**	**31,503**	**28,764**	**42,501**	**58,877**	**6,48,651**

Table - 15A Number of Year Wise Registered Motor Vehicles in Dhaka City [18]

Types of vehicles	**Before 1995**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	Total
Motor car	*36,998*	*6,923*	*8,386*	*6,528*	*4,984*	*4,330*	*2,452*	*5,560*	*5,542*	***81,703***
Jeep/Station Wagon/Micorbus	*17,937*	*1,553*	*1,387*	*1,492*	*1,438*	*1,371*	*910*	*1,579*	*2,911*	***30,581***
Taxi	*787*	*25*	*35*	*14*	*102*	*215*	*348*	*762*	*2101*	***4,389***
Bus	*269*	*145*	*73*	*58*	*184*	*224*	*202*	*453*	*632*	***2,240***
Minibus	*2,009*	*324*	*167*	*397*	*300*	*215*	*242*	*831*	*1,924*	***6,409***
Truck	*9,775*	*802*	*615*	*834*	*1,681*	*855*	*1,635*	*890*	*1,127*	***18,214***
Auto-rickshaws/Tempo	*8,359*	*7,301*	*4,615*	*1,902*	*1,679*	*682*	*1,881*	*75*	*2,616*	***29,120***
Motorcycle	*61,478*	*4,427*	*4,027*	*5,346*	*4,992*	*5,330*	*8,768*	*8,590*	*9,102*	***1,12,060***
Others	*2,063*	*878*	*828*	*310*	*196*	*1,392*	*819*	*1,825*	*1,012*	***9,257***
Total	**1,39,675**	**22,381**	**20,133**	**16,881**	**15,566**	**14,614**	**17,257**	**20,565**	**26,967**	**2,93,073**

Table – 16A Comparison of Road Transportation in Selection Asian Cities [2]

		Dhaka *(1995)*	**Jakarta** *(1994)*	**Bangkok** *(1995)*	**Manila** *(1995)*
Population (000)		6,900	9,175	8,126	9,454
Urban Area (Km^2)		360	670	600	630
Road (km)	***Major***	310	1,406	1,080	977
	Minor	2,692	5,469	2,825	2,099
	Total	3,002	5,875	3,905	3,076
Availability of Motorable Roads	***Km/thousand People***	0.04	0.15	0.13	0.10
	Km/km^2	0.86	2.10	1.80	1.55
Car Ownership (No./thousand)		5	74	141	85

Table – 17A Year Wise Road Accident in Dhaka City [18]

	Nature of Accident			
Year	***Fatal***	***Serious***	***Simple***	***Total***
1998	526	925	115	***1,556***
1999	392	499	188	***1,079***
2000	359	552	35	***946***
2001	364	347	18	***729***
2002	329	199	24	***552***
Total	*1,960*	*2,522*	*380*	**4,788**

Table – 18A Road Vehicular Traffic Composition by Mode [19]

Vehicle	16 Hours Flows (6 Intersections)	%
Car/Jeep/Van	19,580	8.4
Bus	4,999	2.1
Micorbus/Minibus	14,360	6.2
Tempo	9,904	4.2
Auto rickshaws	42,622	18.3
Motorcycle	4,382	1.9
Truck	4,520	1.9
Oil Tanker	434	0.2
Motorized (a)	1,00,801	43.2
Rickshaws	1,22,032	52.3
Bicycle	3,045	1.3
Rickshaw van	6,668	2.9
Push Cart	834	0.4
Non-Motorized (b)	1,32,579	56.8
Total (a+b)	**2,33,380**	**100.0**

Table 19A Average Time Required to Travel the Distance of Different Routes by the Tested Vehicles

Vehicles Speed (km/hr)	Route -1			Route - 2			Route- 3		
	Morning (0900 hrs)	*Noon (1244 hrs)*	*Evening (1645 hrs)*	*Morning (0900 hrs)*	*Noon (1245 hrs)*	*Evening (1645 hrs)*	*Morning (0900 hrs)*	*Noon (1245 hrs)*	*Evening (1645 hrs)*
0	840	285	735	4750	1535	4470	2110	840	2160
0-5	230	15	210	460	255	520	320	50	210
5-10	160	50	180	535	340	510	185	90	190
10-15	80	85	60	310	275	365	145	240	120
15-20	100	120	90	230	150	245	65	150	90
20-25	115	35	120	120	170	145	155	120	145
25-30	50	50	45	75	75	65	65	135	65
30-35	65	30	30	25	25	45	80	50	50
35-40	80	40	60	65	130	55	90	105	80
40-45	50	80	50	25	75	30	65	30	30
45-50	-	10	-	-	55	-	-	-	-
50-55	-	45	-	-	45	-	-	-	-
Total Time (sec)	***1770***	***845***	***1580***	***6595***	***3130***	***6450***	***3280***	***1810***	***3140***

APPENDIX – B

Technical Specifications

Measured Gases	HC Hydrocarbon CO Carbon Monoxide CO_2 Carbon Dioxide O_2 Oxygen
Ranges	HC 0 to 10,000 ppm CO 0 to 10% CO_2 0 to 20 % O_2 0 to 25 %
Accuracy/Performance	OIML R99 Class I HC 12 ppm HC CO 0.06% CO O_2 0.10% O_2 *Absolute or 5% of reading, which ever is wider*
Resolution	HC 1 ppm vol. CO 0.01% vol CO_2 0.1% vol O_2 0.01% vol
RPM	0 – 10,000 rom with DIS/Wankel and 4 stroke selection
Oil Temperature	0 – 120° C
Lambda	Calculated using Brett Schneider formula. Resolution: 0.001. Fuel type selection: Leaded, unleaded, LPG or CNG.
Environmental	Operating Temperature - + 5 to + 40^0 C Storage Temperature - -20 to + 55^0 C
Response Time	11 secs to 95% of final reading with 6 meter sample hose.
Operating Pressure	750 – 1100 mbar 1000 mbar nominal
Warm-up Time	Less than 10 minutes (self controlled) at 20 C for OIML R99 Class I

APPENDIX - C

TABLES

Table – 1C Measured characteristics data of vehicle no. –1 driven on route no. –1 at morning peak (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	840	0.19	12.3	387	15.1	0.336	0.0227	0.3440	366.8	0.700	45.113	0.142
0–5	907	230	0.19	12.3	413	14.6	0.092	0.0062	0.0911	97.3	0.185	11.969	0.040
5–10	1087	160	0.67	12.4	382	14.4	0.064	0.0043	0.0625	66.8	0.448	8.286	0.026
10-15	1378	80	0.41	12.6	285	14.6	0.032	0.0021	0.0317	33.8	0.139	4.265	0.010
15-20	1554	100	0.39	12.9	253	14.6	0.04	0.0027	0.0396	42.3	0.165	5.458	0.011
20-25	1842	115	0.59	13	252	14.7	0.046	0.0031	0.0458	49.0	0.289	6.365	0.012
25-30	2029	50	0.45	13.1	315	14.5	0.02	0.0013	0.0200	21.0	0.095	2.753	0.007
30-35	2289	65	0.35	12.9	332	14.4	0.026	0.0017	0.0254	27.1	0.095	3.502	0.009
35-40	2429	80	0.34	12.8	325	14.2	0.032	0.0021	0.0308	33.0	0.112	4.221	0.011
40-45	2643	50	0.35	12.8	282	13.9	0.02	0.0013	0.0188	20.2	0.071	2.586	0.006
		1770					**0.708**	**0.0480**			**2.295**	**94.518**	**0.272**

Table – 2C Measured characteristics data of vehicle no. –1 driven on the route no. –1 at noon off-peak hour (1245 hrs).

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	285	0.19	12.3	387	15.1	0.114	0.0077	0.1167	124.4	0.236	15.306	0.048
0–5	907	15	0.19	12.3	413	14.6	0.006	0.0004	0.0059	6.3	0.012	0.781	0.003
5–10	1087	50	0.67	12.4	382	14.4	0.02	0.0014	0.0195	20.9	0.140	2.589	0.008
10-15	1378	85	0.41	12.6	285	14.6	0.034	0.0023	0.0337	36.0	0.147	4.531	0.010
15-20	1554	120	0.39	12.9	253	14.6	0.048	0.0033	0.0475	50.8	0.198	6.549	0.013
20-25	1842	35	0.59	13	252	14.7	0.014	0.0009	0.0140	14.9	0.088	1.937	0.004
25-30	2029	50	0.45	13.1	315	14.5	0.02	0.0014	0.0197	21.0	0.095	2.753	0.007
30-35	2289	30	0.35	12.9	332	14.4	0.012	0.0008	0.0117	12.5	0.044	1.616	0.005
35-40	2429	40	0.34	12.8	325	14.2	0.016	0.0011	0.0154	16.5	0.056	2.111	0.005
40-45	2643	80	0.35	12.8	282	13.9	0.032	0.0022	0.0302	32.3	0.113	4.138	0.009
45-50	2845	10	0.35	12.8	276	13.4	0.004	0.0003	0.0036	3.9	0.014	0.500	0.001
50-55	3049	45	0.35	12.8	247	12.8	0.018	0.0012	0.0156	16.8	0.059	2.156	0.004
		845					**0.338**	**0.0229**			**1.202**	**44.967**	**0.116**

Table – 3C Measured characteristics data of vehicle no. –1 driven on route no. –1 at evening peak (1645 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	713	735	0.19	12.3	387	15.1	0.294	0.0199	0.3010	320.9	0.610	39.474	0.124
0–5	907	210	0.19	12.3	413	14.6	0.084	0.0057	0.0832	88.8	0.169	10.928	0.037
5–10	1087	180	0.67	12.4	382	14.4	0.072	0.0049	0.0703	75.2	0.504	9.322	0.029
10-15	1378	60	0.41	12.6	285	14.6	0.024	0.0016	0.0238	25.4	0.104	3.198	0.007
15-20	1554	90	0.39	12.9	253	14.6	0.036	0.0024	0.0356	38.1	0.148	4.912	0.010
20-25	1842	120	0.59	13.0	252	14.7	0.048	0.0033	0.0478	51.1	0.301	6.642	0.013
25-30	2029	45	0.45	13.1	315	14.5	0.018	0.0012	0.0177	18.9	0.085	2.478	0.006
30-35	2289	30	0.35	12.9	332	14.4	0.012	0.0008	0.0117	12.5	0.044	1.616	0.004
35-40	2429	60	0.34	12.8	325	14.2	0.024	0.0016	0.0231	24.7	0.084	3.166	0.008
40-45	2643	50	0.35	12.8	282	13.9	0.02	0.0014	0.0188	20.2	0.071	2.586	0.006
		1580					**0.632**	**0.0429**			**2.120**	**84.322**	**0.243**

Table – 4C Measured characteristics data of vehicle no. –2 driven on route no. –1 at morning peak (0900 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	712	840	0.57	13.8	228	15.2	0.336	0.0227	0.3463	369.0	2.104	50.929	0.084
0–5	1091	230	0.35	14.0	155	15.4	0.092	0.0062	0.0961	102.3	0.358	14.322	0.016
5–10	1277	160	0.32	13.9	129	15.6	0.064	0.0043	0.0677	72.0	0.230	10.012	0.009
10-15	1524	80	0.36	14.0	119	15.4	0.032	0.0021	0.0334	35.6	0.128	4.981	0.004
15-20	1761	100	0.44	14.1	121	15.2	0.040	0.0027	0.0412	43.9	0.193	6.195	0.005
20-25	2164	115	0.53	14.2	117	15.1	0.046	0.0031	0.0471	50.2	0.266	7.130	0.006
25-30	2221	50	0.57	14.2	115	15.1	0.020	0.0013	0.0205	21.8	0.124	3.100	0.003
30-35	2438	65	0.60	14.1	97	15.1	0.026	0.0017	0.0266	28.4	0.170	4.002	0.003
35-40	2632	80	0.62	14.1	90	15.0	0.032	0.0021	0.0325	34.7	0.215	4.895	0.003
40-45	2929	50	0.57	14.2	89	15.0	0.020	0.0013	0.0203	21.7	0.124	3.081	0.002
		1770					**0.708**	**0.0480**			**3.913**	**108.646**	**0.135**

Table –5C Measured characteristics data of vehicle no. –2 driven on route no. –1 at noon off-peak hour (1245 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	712	285	0.57	13.8	228	15.2	0.114	0.0077	0.1175	125.2	0.714	17.279	0.029
0–5	1091	15	0.35	14.0	155	15.4	0.006	0.0004	0.0063	6.7	0.023	0.934	0.001
5–10	1277	50	0.32	13.9	129	15.6	0.020	0.0013	0.0212	22.5	0.072	3.129	0.003
10-15	1524	85	0.36	14.0	119	15.4	0.034	0.0023	0.0355	37.8	0.136	5.293	0.004
15-20	1761	120	0.44	14.1	121	15.2	0.048	0.0032	0.0495	52.7	0.232	7.434	0.006
20-25	2164	35	0.53	14.2	117	15.1	0.014	0.0009	0.0143	15.3	0.081	2.170	0.002
25-30	2221	50	0.57	14.2	115	15.1	0.020	0.0013	0.0205	21.8	0.124	3.100	0.003
30-35	2438	30	0.60	14.1	97	15.1	0.012	0.0008	0.0123	13.1	0.079	1.847	0.001
35-40	2632	40	0.62	14.1	90	15.0	0.016	0.0010	0.0163	17.4	0.108	2.447	0.002
40-45	2929	80	0.57	14.2	89	15.0	0.032	0.0021	0.0325	34.7	0.198	4.929	0.003
45-50	3023	55	0.54	14.4	87	14.9	0.022	0.0014	0.0222	23.7	0.128	3.415	0.002
		845					**0.338**	**0.0229**			**1.895**	**51.978**	**0.056**

Table –6C Measured characteristics data of vehicle no. –2 driven on route no. –1 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	712	735	0.57	13.8	228	15.2	0.279	0.0189	0.2878	306.8	1.749	42.335	0.070
0–5	1091	210	0.35	14.0	155	15.4	0.080	0.0054	0.0833	88.7	0.311	12.422	0.014
5–10	1277	180	0.32	13.9	129	15.6	0.068	0.0046	0.0723	77.0	0.246	10.701	0.010
10-15	1524	60	0.36	14.0	119	15.4	0.023	0.0015	0.0238	25.4	0.091	3.549	0.003
15-20	1761	90	0.44	14.1	121	15.2	0.034	0.0023	0.0352	37.6	0.165	5.297	0.005
20-25	2164	120	0.53	14.2	117	15.1	0.046	0.0030	0.0466	49.8	0.264	7.068	0.006
25-30	2221	45	0.57	14.2	115	15.1	0.017	0.0011	0.0175	18.7	0.106	2.651	0.002
30-35	2438	30	0.60	14.1	97	15.1	0.011	0.0007	0.0116	12.4	0.075	1.755	0.001
35-40	2632	60	0.62	14.1	90	15.0	0.023	0.0015	0.0231	24.7	0.153	3.487	0.002
40-45	2929	50	0.57	14.2	89	15.0	0.019	0.0012	0.0193	20.6	0.117	2.927	0.002
		1580					***0.600***	***0.0407***			***3.278***	***92.191***	***0.114***

Table –7C Measured characteristics data of vehicle no. –3 driven on route no. –1 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	858	840	4.05	10.7	1063	14.0	0.336	0.0227	0.3189	341.7	13.839	36.563	0.363
0–5	1027	230	3.95	10.6	1329	14.0	0.092	0.0062	0.0873	93.6	3.696	9.918	0.124
5–10	1231	160	4.39	10.3	1401	13.7	0.064	0.0043	0.0594	63.8	2.800	6.570	0.089
10-15	1554	80	6.78	9.0	1460	12.6	0.032	0.0021	0.0273	29.5	2.001	2.656	0.043
15-20	1728	100	7.21	9.2	1181	12.2	0.040	0.0027	0.0331	35.8	2.581	3.293	0.042
20-25	2198	115	6.94	9.0	1304	12.4	0.046	0.0031	0.0387	41.8	2.900	3.761	0.054
25-30	2454	50	7.10	9.1	1245	12.4	0.020	0.0013	0.0168	18.2	1.290	1.654	0.023
30-35	2691	65	7.32	9.0	1146	12.2	0.026	0.0017	0.0215	23.3	1.703	2.094	0.027
35-40	2790	80	7.50	9.0	1103	12.1	0.032	0.0021	0.0263	28.4	2.132	2.558	0.031
40-45	2889	50	7.93	9.0	1049	12.0	0.020	0.0013	0.0163	17.6	1.398	1.587	0.018
		1770					**0.708**	**0.0480**			**34.340**	**70.653**	**0.816**

Table – 8C Measured characteristics data of vehicle no. –3 driven on route no. –1 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	858	285	4.05	10.7	1063	14.0	0.114	0.0077	0.1082	115.9	4.695	12.405	0.123
0–5	1027	15	3.95	10.6	1329	14.0	0.006	0.0004	0.0057	6.1	0.241	0.647	0.008
5–10	1231	50	4.39	10.3	1401	13.7	0.020	0.0013	0.0186	19.9	0.875	2.053	0.028
10-15	1554	85	6.78	9.0	1460	12.6	0.034	0.0023	0.0290	31.4	2.126	2.822	0.046
15-20	1728	120	7.21	9.2	1181	12.2	0.048	0.0032	0.0397	43.0	3.097	3.952	0.051
20-25	2198	35	6.94	9.0	1304	12.4	0.014	0.0009	0.0118	12.7	0.883	1.145	0.017
25-30	2454	50	7.10	9.1	1245	12.4	0.020	0.0013	0.0168	18.2	1.290	1.654	0.023
30-35	2691	30	7.32	9.0	1146	12.2	0.012	0.0008	0.0099	10.7	0.786	0.967	0.012
35-40	2790	40	7.50	9.0	1103	12.1	0.016	0.0010	0.0131	14.2	1.066	1.279	0.016
40-45	2889	80	7.93	9.0	1049	12.0	0.032	0.0021	0.0260	28.2	2.237	2.538	0.030
45-50	3012	55	7.90	9.0	1040	12.0	0.022	0.0014	0.0179	19.4	1.532	1.745	0.020
		845					**0.338**	**0.0229**			**18.828**	**31.206**	**0.373**

Table – 9C Measured characteristics data of vehicle no. –3 driven on route no. –1 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	735	4.05	10.7	1063	14.0	0.294	0.0199	0.2791	299.0	12.109	31.993	0.318
0–5	907	210	3.95	10.6	1329	14.0	0.084	0.0056	0.0797	85.4	3.374	9.055	0.114
5–10	1087	180	4.39	10.3	1401	13.7	0.072	0.0048	0.0669	71.8	3.150	7.391	0.101
10-15	1378	60	6.78	9.0	1460	12.6	0.024	0.0016	0.0205	22.1	1.500	1.992	0.032
15-20	1554	90	7.21	9.2	1181	12.2	0.036	0.0024	0.0298	32.2	2.323	2.964	0.038
20-25	1842	120	6.94	9.0	1304	12.4	0.048	0.0032	0.0404	43.6	3.026	3.925	0.057
25-30	2029	45	7.10	9.1	1245	12.4	0.018	0.0012	0.0151	16.4	1.161	1.488	0.020
30-35	2289	30	7.32	9.0	1146	12.2	0.012	0.0008	0.0099	10.7	0.786	0.967	0.012
35-40	2429	60	7.50	9.0	1103	12.1	0.024	0.0016	0.0197	21.3	1.599	1.918	0.024
40-45	2643	50	7.93	9.0	1049	12.0	0.020	0.0013	0.0163	17.6	0.001	1.587	0.018
		1580					**0.632**	**0.0428**			**29.031**	**63.280**	**0.734**

Table – 10C Measured characteristics data of vehicle no. –4 driven on route no. –1 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	945	840	6.10	10.6	408	12.2	0.336	0.0227	0.2779	300.7	18.343	31.875	0.123
0–5	1025	230	5.51	10.4	407	12.8	0.092	0.0062	0.0798	86.1	4.743	8.952	0.035
5–10	1251	160	6.06	10.7	417	12.4	0.064	0.0043	0.0538	58.1	3.524	6.222	0.024
10-15	1551	80	5.93	10.8	428	12.4	0.032	0.0021	0.0269	29.1	1.724	3.140	0.012
15-20	1727	100	4.96	11.3	387	12.8	0.040	0.0027	0.0347	37.4	1.856	4.229	0.014
20-25	2059	115	4.47	11.5	335	13.1	0.046	0.0031	0.0409	44.0	1.966	5.057	0.015
25-30	2236	50	4.62	11.6	320	13.1	0.020	0.0013	0.0178	19.1	0.883	2.218	0.006
30-35	2425	65	5.02	11.4	307	12.9	0.026	0.0017	0.0227	24.5	1.230	2.793	0.008
35-40	2608	80	4.83	11.5	285	12.9	0.032	0.0021	0.0280	30.2	1.457	3.468	0.009
40-45	2845	50	5.17	11.5	257	12.8	0.020	0.0013	0.0176	18.7	0.967	2.152	0.005
		1770					**0.708**	**0.0480**			**36.693**	**70.106**	**0.251**

Table – 11C Measured characteristics data of vehicle no. –4 driven on route no. –1 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	285	6.10	10.6	408	12.2	0.114	0.0077	0.0943	102.0	6.224	10.815	0.042
0–5	907	15	5.51	10.4	407	12.8	0.006	0.0004	0.0052	5.6	0.309	0.584	0.002
5–10	1087	50	6.06	10.7	417	12.4	0.020	0.0013	0.0168	18.2	1.101	1.944	0.008
10-15	1378	85	5.93	10.8	428	12.4	0.034	0.0023	0.0286	30.9	1.832	3.336	0.013
15-20	1554	120	4.96	11.3	387	12.8	0.048	0.0032	0.0417	44.9	2.228	5.075	0.017
20-25	1842	35	4.47	11.5	335	13.1	0.014	0.0009	0.0124	13.4	0.598	1.539	0.004
25-30	2029	50	4.62	11.6	320	13.1	0.020	0.0013	0.0178	19.1	0.883	2.218	0.006
30-35	2289	30	5.02	11.4	307	12.9	0.012	0.0008	0.0105	11.3	0.568	1.289	0.003
35-40	2429	40	4.83	11.5	285	12.9	0.016	0.0010	0.0140	15.1	0.728	1.734	0.004
40-45	2643	80	5.17	11.5	257	12.8	0.032	0.0021	0.0278	29.9	1.548	3.443	0.008
45-50	2998	55	5.24	11.8	248	12.8	0.022	0.0014	0.0191	20.6	1.079	2.429	0.005
		845					**0.338**	**0.0220**			**17.097**	**34.406**	**0.113**

Table – 12C Measured characteristics data of vehicle no. –4 driven on route no. –1 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	713	735	6.10	10.6	408	12.2	0.294	0.0199	0.2432	263.1	16.050	27.891	0.107
0–5	907	210	5.51	10.4	407	12.8	0.084	0.0056	0.0729	78.6	4.331	8.174	0.032
5–10	1087	180	6.06	10.7	417	12.4	0.072	0.0048	0.0605	65.4	3.964	6.999	0.027
10-15	1378	60	5.93	10.8	428	12.4	0.024	0.0016	0.0202	21.8	1.293	2.355	0.009
15-20	1554	90	4.96	11.3	387	12.8	0.036	0.0024	0.0312	33.7	1.671	3.806	0.013
20-25	1842	120	4.47	11.5	335	13.1	0.048	0.0032	0.0426	45.9	2.051	5.277	0.015
25-30	2029	45	4.62	11.6	320	13.1	0.018	0.0012	0.0160	17.2	0.795	1.996	0.006
30-35	2289	30	5.02	11.4	307	12.9	0.012	0.0008	0.0105	11.3	0.568	1.289	0.003
35-40	2429	60	4.83	11.5	285	12.9	0.024	0.0016	0.0210	22.6	1.092	2.601	0.006
40-45	2643	50	5.17	11.5	257	12.8	0.020	0.0013	0.0174	18.7	0.967	2.152	0.005
		1580					**0.632**	**0.0428**			**32.782**	**62.540**	**0.225**

Table – 13C Measured characteristics data of vehicle no. –5 driven on route no. –1 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	656	840	0.54	13.3	355	15.6	0.336	0.0227	0.3554	378.2	2.042	50.295	0.134
0–5	1075	230	0.74	13.6	255	15.2	0.092	0.0062	0.0948	101.0	0.748	13.743	0.026
5–10	1201	160	0.88	13.6	202	15.1	0.064	0.0043	0.0655	69.9	0.615	9.501	0.014
10-15	1501	80	0.75	13.7	185	15.2	0.032	0.0021	0.0330	35.1	0.264	4.815	0.007
15-20	1723	100	0.68	13.7	159	15.1	0.040	0.0027	0.0410	43.7	0.297	5.982	0.007
20-25	2009	115	0.80	13.8	138	15.1	0.046	0.0031	0.0471	50.2	0.402	6.929	0.007
25-30	2221	50	0.81	13.8	132	15.1	0.020	0.0013	0.0205	21.8	0.177	3.013	0.003
30-35	2438	65	0.83	13.8	105	15.1	0.026	0.0017	0.0266	28.4	0.236	3.917	0.003
35-40	2632	80	0.80	13.8	98	15.1	0.032	0.0021	0.0327	34.9	0.279	4.820	0.003
40-45	2929	50	0.76	13.9	101	15.0	0.020	0.0013	0.0203	21.7	0.165	3.016	0.002
		1770					**0.708**	**0.0480**			**5.224**	**106.031**	**0.206**

Table – 14C Measured characteristics data of vehicle no. –5 driven on route no. –1 at noon off-peak hour (1245 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	656	285	0.54	13.3	355	15.6	0.114	0.0077	0.1206	128.3	0.693	17.065	0.046
0–5	1075	15	0.74	13.6	255	15.2	0.006	0.0004	0.0062	6.6	0.049	0.896	0.002
5–10	1201	50	0.88	13.6	202	15.1	0.020	0.0013	0.0205	21.8	0.192	2.969	0.004
10-15	1501	85	0.75	13.7	185	15.2	0.034	0.0023	0.0350	37.3	0.280	5.116	0.007
15-20	1723	120	0.68	13.7	159	15.1	0.048	0.0032	0.0491	52.4	0.356	7.178	0.008
20-25	2009	35	0.80	13.8	138	15.1	0.014	0.0009	0.0143	15.3	0.122	2.109	0.002
25-30	2221	50	0.81	13.8	132	15.1	0.020	0.0013	0.0205	21.8	0.177	3.013	0.003
30-35	2438	30	0.83	13.8	105	15.1	0.012	0.0008	0.0123	13.1	0.109	1.808	0.001
35-40	2632	40	0.80	13.8	98	15.1	0.016	0.0010	0.0164	17.5	0.140	2.410	0.002
40-45	2929	80	0.76	13.9	101	15.0	0.032	0.0021	0.0325	34.7	0.264	4.825	0.004
45-50	3032	55	0.75	13.9	105	15.0	0.022	0.0014	0.0224	23.9	0.179	3.317	0.003
		845					**0.338**	**0.0229**			**2.560**	**50.706**	**0.081**

Table – 15C Measured characteristics data of vehicle no. –5 driven on route no. –1 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	656	735	0.54	13.3	355	15.6	0.294	0.0199	0.3110	330.9	1.787	44.009	0.117
0–5	1075	210	0.74	13.6	255	15.2	0.084	0.0056	0.0866	92.3	0.683	12.548	0.024
5–10	1201	180	0.88	13.6	202	15.1	0.072	0.0048	0.0737	78.6	0.692	10.689	0.016
10-15	1501	60	0.75	13.7	185	15.2	0.024	0.0016	0.0247	26.4	0.198	3.611	0.005
15-20	1723	90	0.68	13.7	159	15.1	0.036	0.0024	0.0369	39.3	0.267	5.384	0.006
20-25	2009	120	0.80	13.8	138	15.1	0.048	0.0032	0.0491	52.4	0.419	7.231	0.007
25-30	2221	45	0.81	13.8	132	15.1	0.018	0.0012	0.0184	19.6	0.159	2.711	0.003
30-35	2438	30	0.83	13.8	105	15.1	0.012	0.0008	0.0123	13.1	0.109	1.808	0.001
35-40	2632	60	0.80	13.8	98	15.1	0.024	0.0016	0.0246	26.2	0.210	3.615	0.003
40-45	2929	50	0.76	13.9	101	15.0	0.020	0.0013	0.0203	21.7	0.165	3.016	0.002
		1580					**0.632**	**0.0428**			**4.688**	**94.621**	**0.184**

Table – 16C Measured characteristics data of vehicle no. –6 driven on route no. –1 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	840	0.17	14.4	484	15.0	0.336	0.0227	0.3417	364.5	0.620	52.487	0.176
0–5	1042	230	0.15	14.4	468	15.0	0.092	0.0062	0.0936	99.8	0.150	14.371	0.047
5–10	1250	160	0.23	14.4	392	15.0	0.064	0.0043	0.0651	69.4	0.160	9.998	0.027
10-15	1568	80	0.23	14.5	288	15.1	0.032	0.0021	0.0328	34.9	0.080	5.065	0.010
15-20	1778	100	0.24	14.5	257	15.1	0.040	0.0027	0.0410	43.7	0.105	6.331	0.011
20-25	2104	115	0.31	14.5	196	15.1	0.046	0.0031	0.0471	50.2	0.156	7.281	0.010
25-30	2454	50	0.35	14.5	188	15.1	0.020	0.0013	0.0205	21.8	0.076	3.166	0.004
30-35	2664	65	0.41	14.3	178	15.1	0.026	0.0017	0.0266	28.4	0.116	4.058	0.005
35-40	2790	80	0.43	14.3	171	15.0	0.032	0.0021	0.0325	34.7	0.149	4.964	0.006
40-45	2889	50	0.47	14.3	169	13.9	0.020	0.0013	0.0188	20.2	0.095	2.889	0.003
		1770					**0.708**	**0.0480**			**1.707**	**110.610**	**0.300**

Table – 17C Measured characteristics data of vehicle no. –6 driven on route no. –1 at noon off-peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	285	0.17	14.4	484	15.0	0.114	0.0077	0.1159	123.7	0.210	17.808	0.060
0–5	1042	15	0.15	14.4	468	15.0	0.006	0.0004	0.0061	6.5	0.010	0.937	0.003
5–10	1250	50	0.23	14.4	392	15.0	0.020	0.0013	0.0203	21.7	0.050	3.124	0.009
10-15	1568	85	0.23	14.5	288	15.1	0.034	0.0023	0.0348	37.1	0.085	5.381	0.011
15-20	1778	120	0.24	14.5	257	15.1	0.048	0.0032	0.0491	52.4	0.126	7.597	0.013
20-25	2104	35	0.31	14.5	196	15.1	0.014	0.0009	0.0143	15.3	0.047	2.216	0.003
25-30	2454	50	0.35	14.5	188	15.1	0.020	0.0013	0.0205	21.8	0.076	3.166	0.004
30-35	2664	30	0.41	14.3	178	15.1	0.012	0.0008	0.0123	13.1	0.054	1.873	0.002
35-40	2790	40	0.43	14.3	171	15.0	0.016	0.0010	0.0163	17.4	0.075	2.482	0.003
40-45	2889	80	0.47	14.3	169	13.9	0.032	0.0021	0.0302	32.3	0.152	4.623	0.005
45-50	3023	55	0.48	14.5	168	13.9	0.022	0.0014	0.0207	22.2	0.107	3.223	0.004
		845					**0.338**	**0.0229**			**0.992**	**52.430**	**0.117**

Table – 18C Measured characteristics data of vehicle no. –6 driven on the route no. –1 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	735	0.17	14.4	484	15.0	0.294	0.0199	0.2990	318.9	0.542	45.926	0.154
0–5	1042	210	0.15	14.4	468	15.0	0.084	0.0056	0.0854	91.1	0.137	13.122	0.043
5–10	1250	180	0.23	14.4	392	15.0	0.072	0.0048	0.0732	78.1	0.180	11.247	0.031
10-15	1568	60	0.23	14.5	288	15.1	0.024	0.0016	0.0246	26.2	0.060	3.799	0.008
15-20	1778	90	0.24	14.5	257	15.1	0.036	0.0024	0.0369	39.3	0.094	5.698	0.010
20-25	2104	120	0.31	14.5	196	15.1	0.048	0.0032	0.0491	52.4	0.162	7.597	0.010
25-30	2454	45	0.35	14.5	188	15.1	0.018	0.0012	0.0184	19.6	0.069	2.849	0.004
30-35	2664	30	0.41	14.3	178	15.1	0.012	0.0008	0.0123	13.1	0.054	1.873	0.002
35-40	2790	60	0.43	14.3	171	15.0	0.024	0.0016	0.0244	26.0	0.112	3.723	0.004
40-45	2889	50	0.47	14.3	169	13.9	0.020	0.0013	0.0188	20.2	0.095	2.889	0.003
		1580					**0.632**	**0.0428**			**1.505**	**98.724**	**0.269**

Table – 19C Measured characteristics data of vehicle no. –1 driven on route no. –2 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	4750	0.19	12.3	387	15.1	1.900	0.1288	1.9452	2074.0	3.941	255.102	0.803
0–5	907	460	0.19	12.3	413	14.6	0.184	0.0125	0.1821	194.6	0.370	23.937	0.080
5–10	1087	535	0.67	12.4	382	14.4	0.214	0.0145	0.2089	223.4	1.497	27.707	0.085
10-15	1378	310	0.41	12.6	285	14.6	0.124	0.0084	0.1227	131.2	0.538	16.525	0.037
15-20	1554	230	0.39	12.9	253	14.6	0.092	0.0062	0.0911	97.3	0.379	12.553	0.025
20-25	1842	120	0.59	13.0	252	14.7	0.048	0.0033	0.0478	51.1	0.301	6.642	0.013
25-30	2029	75	0.45	13.1	315	14.5	0.030	0.0020	0.0295	31.5	0.142	4.130	0.010
30-35	2289	25	0.35	12.9	332	14.4	0.010	0.0007	0.0098	10.4	0.037	1.347	0.003
35-40	2429	65	0.34	12.8	325	14.2	0.026	0.0018	0.0250	26.8	0.091	3.430	0.009
40-45	2643	25	0.35	12.8	282	13.9	0.010	0.0007	0.0094	10.1	0.035	1.293	0.003
		6595					**2.638**	**0.1789**			**7.331**	**352.666**	**1.068**

Table – 20C Measured characteristics data of vehicle no. –1 driven on route no. –2 at noon 0oo- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	1535	0.19	12.3	387	15.1	0.614	0.0416	0.6286	670.2	1.273	82.438	0.259
0–5	907	255	0.19	12.3	413	14.6	0.102	0.0069	0.1010	107.9	0.205	13.270	0.045
5–10	1087	340	0.67	12.4	382	14.4	0.136	0.0092	0.1328	142.0	0.951	17.608	0.054
10-15	1378	275	0.41	12.6	285	14.6	0.110	0.0074	0.1089	116.3	0.477	14.659	0.033
15-20	1554	150	0.39	12.9	253	14.6	0.060	0.0040	0.0594	63.5	0.247	8.186	0.016
20-25	1842	170	0.59	13.0	252	14.7	0.068	0.0046	0.0678	72.4	0.427	9.410	0.018
25-30	2029	75	0.45	13.1	315	14.5	0.030	0.0020	0.0295	31.5	0.142	4.130	0.010
30-35	2289	25	0.35	12.9	332	14.4	0.010	0.0006	0.0098	10.4	0.037	1.347	0.003
35-40	2429	130	0.34	12.8	325	14.2	0.052	0.0035	0.0501	53.6	0.182	6.859	0.017
40-45	2643	75	0.35	12.8	282	13.9	0.030	0.0020	0.0283	30.3	0.106	3.879	0.009
45-50	2845	55	0.35	12.8	276	13.4	0.022	0.0014	0.0200	21.5	0.075	2.749	0.006
50-55	3049	45	0.35	12.8	247	12.8	0.018	0.0012	0.0156	16.8	0.059	2.156	0.004
		3130					**1.252**	**0.0848**			**4.182**	**166.692**	**0.475**

Table – 21C Measured characteristics data of vehicle no. –1 driven on route no. –2 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	4470	0.19	12.3	387	15.1	1.788	0.1212	1.8305	1951.7	3.708	240.065	0.755
0–5	907	520	0.19	12.3	413	14.6	0.208	0.0141	0.2059	220.0	0.418	27.060	0.091
5–10	1087	510	0.67	12.4	382	14.4	0.204	0.0138	0.1992	213.0	1.427	26.412	0.081
10-15	1378	365	0.41	12.6	285	14.6	0.146	0.0099	0.1445	154.4	0.633	19.457	0.044
15-20	1554	245	0.39	12.9	253	14.6	0.098	0.0066	0.0970	103.7	0.404	13.371	0.026
20-25	1842	145	0.59	13.0	252	14.7	0.058	0.0039	0.0578	61.7	0.364	8.026	0.016
25-30	2029	65	0.45	13.1	315	14.5	0.026	0.0018	0.0256	27.3	0.123	3.579	0.009
30-35	2289	45	0.35	12.9	332	14.4	0.018	0.0012	0.0176	18.8	0.066	2.424	0.006
35-40	2429	55	0.34	12.8	325	14.2	0.022	0.0015	0.0212	22.7	0.077	2.902	0.007
40-45	2643	30	0.35	12.8	282	13.9	0.012	0.0008	0.0113	12.1	0.042	1.552	0.003
		6450					**2.580**	**0.1749**			**7.263**	**344.848**	**1.039**

Table – 22C Measured characteristics data of vehicle no. –2 driven on route no. –2 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	712	4750	0.57	13.8	228	15.2	1.900	0.1288	1.9581	2086.9	11.895	287.990	0.476
0–5	1091	460	0.35	14.0	155	15.4	0.184	0.0124	0.1921	204.6	0.716	28.643	0.032
5–10	1277	535	0.32	13.9	129	15.6	0.214	0.0145	0.2263	240.9	0.771	33.479	0.031
10-15	1524	310	0.36	14.0	119	15.4	0.124	0.0084	0.1295	137.9	0.496	19.303	0.016
15-20	1761	230	0.44	14.1	121	15.2	0.092	0.0062	0.0948	101.0	0.445	14.248	0.012
20-25	2164	120	0.53	14.2	117	15.1	0.048	0.0032	0.0491	52.4	0.278	7.440	0.006
25-30	2221	75	0.57	14.2	115	15.1	0.030	0.0020	0.0307	32.7	0.187	4.650	0.004
30-35	2438	25	0.60	14.1	97	15.1	0.010	0.0006	0.0102	10.9	0.065	1.539	0.001
35-40	2632	65	0.62	14.1	90	15.0	0.026	0.0017	0.0264	28.2	0.175	3.977	0.003
40-45	2929	25	0.57	14.2	89	15.0	0.010	0.0006	0.0102	10.8	0.062	1.540	0.001
		6595					**2.638**	**0.1788**			**15.090**	**402.809**	**0.582**

Table – 23C Measured characteristics data of vehicle no. –2 driven on route no. –2 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	712	1535	0.57	13.8	228	15.2	0.614	0.0416	0.6328	674.4	3.844	93.066	0.154
0–5	1091	255	0.35	14.0	155	15.4	0.102	0.0069	0.1065	113.4	0.397	15.878	0.018
5–10	1277	340	0.32	13.9	129	15.6	0.136	0.0092	0.1438	153.1	0.490	21.276	0.020
10-15	1524	275	0.36	14.0	119	15.4	0.110	0.0075	0.1149	122.3	0.440	17.124	0.015
15-20	1761	150	0.44	14.1	121	15.2	0.060	0.0041	0.0618	65.9	0.290	9.292	0.008
20-25	2164	170	0.53	14.2	117	15.1	0.068	0.0046	0.0696	74.2	0.393	10.540	0.009
25-30	2221	75	0.57	14.2	115	15.1	0.030	0.0020	0.0307	32.7	0.187	4.650	0.004
30-35	2438	25	0.60	14.1	97	15.1	0.010	0.0007	0.0102	10.9	0.065	1.539	0.001
35-40	2632	130	0.62	14.1	90	15.0	0.052	0.0035	0.0529	56.4	0.350	7.954	0.005
40-45	2929	75	0.57	14.2	89	15.0	0.030	0.0020	0.0305	32.5	0.186	4.621	0.003
45-50	3023	100	0.54	14.4	87	14.9	0.040	0.0027	0.0404	43.1	0.233	6.209	0.004
		3130					**1.252**	**0.0849**			**6.875**	**192.150**	**0.239**

Table – 24C Measured characteristics data of vehicle no. –2 driven on route no. –2 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	712	4470	0.57	13.8	228	15.2	1.788	0.1212	1.8426	1963.9	11.194	271.014	0.448
0–5	1091	520	0.35	14.0	155	15.4	0.208	0.0141	0.2172	231.3	0.809	32.379	0.036
5–10	1277	510	0.32	13.9	129	15.6	0.204	0.0138	0.2158	229.6	0.735	31.914	0.030
10-15	1524	365	0.36	14.0	119	15.4	0.146	0.0099	0.1524	162.3	0.584	22.728	0.019
15-20	1761	245	0.44	14.1	121	15.2	0.098	0.0066	0.1010	107.6	0.474	15.177	0.013
20-25	2164	145	0.53	14.2	117	15.1	0.058	0.0039	0.0594	63.3	0.336	8.990	0.007
25-30	2221	65	0.57	14.2	115	15.1	0.026	0.0018	0.0266	28.4	0.162	4.030	0.003
30-35	2438	45	0.60	14.1	97	15.1	0.018	0.0012	0.0184	19.6	0.118	2.770	0.002
35-40	2632	55	0.62	14.1	90	15.0	0.022	0.0015	0.0224	23.9	0.148	3.365	0.002
40-45	2929	30	0.57	14.2	89	15.0	0.012	0.0008	0.0122	13.0	0.074	1.848	0.001
		6450					**2.580**	**0.1749**			**14.634**	**394.216**	**0.561**

Table – 25C Measured characteristics data of vehicle no. –3 driven on route no. –2 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	858	4750	4.05	10.7	1063	14.0	1.900	0.1288	1.8035	1932.3	78.258	206.75	2.054
0–5	1027	460	3.95	10.6	1329	14.0	0.184	0.0125	0.1747	187.1	7.392	19.84	0.249
5–10	1231	535	4.39	10.3	1401	13.7	0.214	0.0145	0.1988	213.3	9.363	21.97	0.299
10-15	1554	310	6.78	9.0	1460	12.6	0.124	0.0084	0.1059	114.3	7.752	10.29	0.167
15-20	1728	230	7.21	9.2	1181	12.2	0.092	0.0062	0.0761	82.3	5.936	7.57	0.097
20-25	2198	120	6.94	9.0	1304	12.4	0.048	0.0033	0.0404	43.6	3.026	3.92	0.057
25-30	2454	75	7.10	9.1	1245	12.4	0.030	0.0020	0.0252	27.3	1.935	2.48	0.034
30-35	2691	25	7.32	9.0	1146	12.2	0.010	0.0007	0.0083	8.9	0.655	0.81	0.010
35-40	2790	65	7.50	9.0	1103	12.1	0.026	0.0018	0.0213	23.1	1.732	2.08	0.025
40-45	2889	25	7.93	9.0	1049	12.0	0.010	0.0007	0.0081	8.8	0.699	0.79	0.009
		6595					**2.638**	**0.1789**			**116.749**	**276.51**	**3.001**

Table – 26C Measured characteristics data of vehicle no. –3 driven on route no. –2 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	858	1535	4.05	10.7	1063	14.0	0.614	0.0416	0.5828	624.4	25.290	66.815	0.664
0–5	1027	255	3.95	10.6	1329	14.0	0.102	0.0069	0.0968	103.7	4.097	10.996	0.138
5–10	1231	340	4.39	10.3	1401	13.7	0.136	0.0092	0.1263	135.5	5.950	13.961	0.190
10-15	1554	275	6.78	9.0	1460	12.6	0.110	0.0075	0.0940	101.4	6.877	9.129	0.148
15-20	1728	150	7.21	9.2	1181	12.2	0.060	0.0041	0.0496	53.7	3.872	4.940	0.063
20-25	2198	170	6.94	9.0	1304	12.4	0.068	0.0046	0.0572	61.8	4.287	5.560	0.081
25-30	2454	75	7.10	9.1	1245	12.4	0.030	0.0020	0.0252	27.3	1.935	2.480	0.034
30-35	2691	25	7.32	9.0	1146	12.2	0.010	0.0007	0.0083	8.9	0.655	0.805	0.010
35-40	2790	130	7.50	9.0	1103	12.1	0.052	0.0035	0.0427	46.2	3.464	4.157	0.051
40-45	2889	75	7.93	9.0	1049	12.0	0.030	0.0020	0.0244	26.4	2.097	2.380	0.028
45-50	3012	100	7.90	9.0	1040	12.0	0.040	0.0027	0.0325	35.3	2.785	3.173	0.037
		3130					**1.252**	**0.0849**			**61.310**	**124.396**	**1.443**

Table – 27C Measured characteristics data of vehicle no. –3 driven on route no. –2 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	713	4470	4.05	10.7	1063	14.0	1.788	0.121	1.697	1818.4	73.645	194.568	1.933
0–5	907	520	3.95	10.6	1329	14.0	0.208	0.014	0.197	211.5	8.356	22.423	0.281
5–10	1087	510	4.39	10.3	1401	13.7	0.204	0.014	0.189	203.3	8.926	20.942	0.285
10-15	1378	365	6.78	9.0	1460	12.6	0.146	0.010	0.125	134.6	9.127	12.116	0.197
15-20	1554	245	7.21	9.2	1181	12.2	0.098	0.007	0.081	87.7	6.324	8.069	0.104
20-25	1842	145	6.94	9.0	1304	12.4	0.058	0.004	0.049	52.7	3.657	4.742	0.069
25-30	2029	65	7.10	9.1	1245	12.4	0.026	0.002	0.022	23.6	1.677	2.150	0.029
30-35	2289	45	7.32	9.0	1146	12.2	0.018	0.001	0.015	16.1	1.179	1.450	0.018
35-40	2429	55	7.50	9.0	1103	12.1	0.022	0.001	0.018	19.5	1.465	1.759	0.022
40-45	2643	30	7.93	9.0	1049	12.0	0.012	0.001	0.010	10.6	0.839	0.952	0.011
		6450	**7.90**	**9.0**			**2.580**	**0.175**			**115.195**	**269.171**	**2.948**

Table – 28C Measured characteristics data of vehicle no. –4 driven on the route no. –2 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	945	4750	6.10	10.6	408	12.2	1.900	0.129	1.572	1700.4	103.726	180.245	0.694
0–5	1025	460	5.51	10.4	407	12.8	0.184	0.012	0.160	172.2	9.486	17.904	0.070
5–10	1251	535	6.06	10.7	417	12.4	0.214	0.015	0.180	194.4	11.782	20.803	0.081
10-15	1551	310	5.93	10.8	428	12.4	0.124	0.008	0.104	112.7	6.681	12.167	0.048
15-20	1727	230	4.96	11.3	387	12.8	0.092	0.006	0.080	86.1	4.270	9.727	0.033
20-25	2059	120	4.47	11.5	335	13.1	0.048	0.003	0.043	45.9	2.051	5.277	0.015
25-30	2236	75	4.62	11.6	320	13.1	0.030	0.002	0.027	28.7	1.325	3.327	0.009
30-35	2425	25	5.02	11.4	307	12.9	0.010	0.001	0.009	9.4	0.473	1.074	0.003
35-40	2608	65	4.83	11.5	285	12.9	0.026	0.002	0.023	24.5	1.183	2.818	0.007
40-45	2845	25	5.17	11.5	257	12.8	0.010	0.001	0.009	9.4	0.484	1.076	0.002
		6595					**2.638**	**0.179**			**141.460**	**254.419**	**0.963**

Table – 29C Measured characteristics data of vehicle no. –4 driven on the route no. –2 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	713	1535	6.10	10.6	408	12.2	0.614	0.042	0.508	549.5	33.520	58.248	0.224
0–5	907	255	5.51	10.4	407	12.8	0.102	0.007	0.089	95.4	5.258	9.925	0.039
5–10	1087	340	6.06	10.7	417	12.4	0.136	0.009	0.114	123.6	7.488	13.221	0.052
10-15	1378	275	5.93	10.8	428	12.4	0.110	0.007	0.092	99.9	5.926	10.793	0.043
15-20	1554	150	4.96	11.3	387	12.8	0.060	0.004	0.052	56.1	2.784	6.344	0.022
20-25	1842	170	4.47	11.5	335	13.1	0.068	0.005	0.060	65.0	2.906	7.476	0.022
25-30	2029	75	4.62	11.6	320	13.1	0.030	0.002	0.027	28.7	1.325	3.327	0.009
30-35	2289	25	5.02	11.4	307	12.9	0.010	0.001	0.009	9.4	0.473	1.074	0.003
35-40	2429	130	4.83	11.5	285	12.9	0.052	0.004	0.045	49.0	2.367	5.636	0.014
40-45	2643	75	5.17	11.5	257	12.8	0.030	0.002	0.026	28.1	1.451	3.228	0.007
45-50	2998	100	5.24	11.8	248	12.8	0.040	0.003	0.035	37.4	1.961	4.416	0.009
		3130					**1.252**	**0.085**			**65.460**	**123.687**	**0.443**

Table – 30C Measured characteristics data of vehicle no. –4 driven on the route no. –2 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	4470	6.10	10.6	408	12.2	1.788	0.121	1.479	1600.2	97.612	169.620	0.653
0–5	907	520	5.51	10.4	407	12.8	0.208	0.014	0.181	194.6	10.723	20.240	0.079
5–10	1087	510	6.06	10.7	417	12.4	0.204	0.014	0.172	185.3	11.231	19.831	0.077
10-15	1378	365	5.93	10.8	428	12.4	0.146	0.010	0.123	132.6	7.866	14.326	0.057
15-20	1554	245	4.96	11.3	387	12.8	0.098	0.007	0.085	91.7	4.548	10.361	0.035
20-25	1842	145	4.47	11.5	335	13.1	0.058	0.004	0.052	55.4	2.478	6.376	0.019
25-30	2029	65	4.62	11.6	320	13.1	0.026	0.002	0.023	24.9	1.148	2.883	0.008
30-35	2289	45	5.02	11.4	307	12.9	0.018	0.001	0.016	17.0	0.852	1.934	0.005
35-40	2429	55	4.83	11.5	285	12.9	0.022	0.001	0.019	20.7	1.001	2.384	0.006
40-45	2643	30	5.17	11.5	257	12.8	0.012	0.001	0.010	11.2	0.580	1.291	0.003
		6450					**2.580**	**0.175**			**138.040**	**249.247**	**0.942**

Table – 31C Measured characteristics data of vehicle no. –5 driven on the route no. –2 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	656	4750	0.54	13.3	355	15.6	1.900	0.129	2.010	2138.4	11.547	284.409	0.759
0–5	1075	460	0.74	13.6	255	15.2	0.184	0.012	0.190	202.1	1.496	27.485	0.052
5–10	1201	535	0.88	13.6	202	15.1	0.214	0.015	0.219	233.6	2.056	31.769	0.047
10-15	1501	310	0.75	13.7	185	15.2	0.124	0.008	0.128	136.2	1.021	18.659	0.025
15-20	1723	230	0.68	13.7	159	15.1	0.092	0.006	0.094	100.4	0.683	13.758	0.016
20-25	2009	120	0.80	13.8	138	15.1	0.048	0.003	0.049	52.4	0.419	7.231	0.007
25-30	2221	75	0.81	13.8	132	15.1	0.030	0.002	0.031	32.7	0.265	4.519	0.004
30-35	2438	25	0.83	13.8	105	15.1	0.010	0.001	0.010	10.9	0.091	1.506	0.001
35-40	2632	65	0.80	13.8	98	15.1	0.026	0.002	0.027	28.4	0.227	3.917	0.003
40-45	2929	25	0.76	13.9	101	15.0	0.010	0.001	0.010	10.8	0.082	1.508	0.001
		6595					**2.638**	**0.179**			**17.888**	**394.761**	**0.916**

Table – 32C Measured characteristics data of vehicle no. –5 driven on the route no. –2 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	656	1535	0.54	13.3	355	15.6	0.614	0.042	0.649	691.0	3.732	91.909	0.245
0–5	1075	255	0.74	13.6	255	15.2	0.102	0.007	0.105	112.0	0.829	15.236	0.029
5–10	1201	340	0.88	13.6	202	15.1	0.136	0.009	0.139	148.5	1.306	20.190	0.030
10-15	1501	275	0.75	13.7	185	15.2	0.110	0.007	0.113	120.8	0.906	16.552	0.022
15-20	1723	150	0.68	13.7	159	15.1	0.060	0.004	0.061	65.5	0.445	8.973	0.010
20-25	2009	170	0.80	13.8	138	15.1	0.068	0.005	0.070	74.2	0.594	10.243	0.010
25-30	2221	75	0.81	13.8	132	15.1	0.030	0.002	0.031	32.7	0.265	4.519	0.004
30-35	2438	25	0.83	13.8	105	15.1	0.010	0.001	0.010	10.9	0.091	1.506	0.001
35-40	2632	130	0.80	13.8	98	15.1	0.052	0.004	0.053	56.8	0.454	7.833	0.006
40-45	2929	75	0.76	13.9	101	15.0	0.030	0.002	0.031	32.5	0.247	4.524	0.003
45-50	3032	100	0.75	13.9	105	15.0	0.040	0.003	0.041	43.4	0.325	6.031	0.005
		3130					**1.252**	**0.085**			**9.195**	**187.518**	**0.366**

Table – 33C Measured characteristics data of vehicle no. –5 driven on route no. –2 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	656	4470	0.54	13.3	355	15.6	1.788	0.121	1.891	2012.4	10.867	267.644	0.714
0–5	1075	520	0.74	13.6	255	15.2	0.208	0.014	0.214	228.5	1.691	31.070	0.058
5–10	1201	510	0.88	13.6	202	15.1	0.204	0.014	0.209	222.7	1.960	30.285	0.045
10-15	1501	365	0.75	13.7	185	15.2	0.146	0.010	0.150	160.4	1.203	21.969	0.030
15-20	1723	245	0.68	13.7	159	15.1	0.098	0.007	0.100	107.0	0.727	14.656	0.017
20-25	2009	145	0.80	13.8	138	15.1	0.058	0.004	0.059	63.3	0.506	8.737	0.009
25-30	2221	65	0.81	13.8	132	15.1	0.026	0.002	0.027	28.4	0.230	3.917	0.004
30-35	2438	45	0.83	13.8	105	15.1	0.018	0.001	0.018	19.6	0.163	2.711	0.002
35-40	2632	55	0.80	13.8	98	15.1	0.022	0.001	0.023	24.0	0.192	3.314	0.002
40-45	2929	30	0.76	13.9	101	15.0	0.012	0.001	0.012	13.0	0.099	1.809	0.001
		6450					**2.580**	**0.175**			**17.638**	**386.112**	**0.883**

Table – 34C Measured characteristics data of vehicle no. –6 driven on the route no. –2 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	4750	0.17	14.4	484	15.0	1.900	0.129	1.932	2061.1	3.504	296.801	0.998
0–5	1042	460	0.15	14.4	468	15.0	0.184	0.012	0.187	199.6	0.299	28.743	0.093
5–10	1250	535	0.23	14.4	392	15.0	0.214	0.015	0.218	232.1	0.534	33.429	0.091
10-15	1568	310	0.23	14.5	288	15.1	0.124	0.008	0.127	135.4	0.311	19.627	0.039
15-20	1778	230	0.24	14.5	257	15.1	0.092	0.006	0.094	100.4	0.241	14.562	0.026
20-25	2104	120	0.31	14.5	196	15.1	0.048	0.003	0.049	52.4	0.162	7.597	0.010
25-30	2454	75	0.35	14.5	188	15.1	0.030	0.002	0.031	32.7	0.115	4.748	0.006
30-35	2664	25	0.41	14.3	178	15.1	0.010	0.001	0.010	10.9	0.045	1.561	0.002
35-40	2790	65	0.43	14.3	171	15.0	0.026	0.002	0.026	28.2	0.121	4.033	0.005
40-45	2889	25	0.47	14.3	169	13.9	0.010	0.001	0.009	10.1	0.047	1.445	0.002
		6595					**2.638**	**0.179**		**2863.0**	**5.380**	**412.546**	**1.272**

Table – 35C Measured characteristics data of vehicle no. –6 driven on the route no. –2 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	1535	0.17	14.4	484	15.0	0.614	0.042	0.624	666.1	1.132	95.914	0.322
0–5	1042	255	0.15	14.4	468	15.0	0.102	0.007	0.104	110.6	0.166	15.934	0.052
5–10	1250	340	0.23	14.4	392	15.0	0.136	0.009	0.138	147.5	0.339	21.245	0.058
10-15	1568	275	0.23	14.5	288	15.1	0.110	0.007	0.113	120.1	0.276	17.411	0.035
15-20	1778	150	0.24	14.5	257	15.1	0.060	0.004	0.061	65.5	0.157	9.497	0.017
20-25	2104	170	0.31	14.5	196	15.1	0.068	0.005	0.070	74.2	0.230	10.763	0.015
25-30	2454	75	0.35	14.5	188	15.1	0.030	0.002	0.031	32.7	0.115	4.748	0.006
30-35	2664	25	0.41	14.3	178	15.1	0.010	0.001	0.010	10.9	0.045	1.561	0.002
35-40	2790	130	0.43	14.3	171	15.0	0.052	0.004	0.053	56.4	0.243	8.067	0.010
40-45	2889	75	0.47	14.3	169	13.9	0.030	0.002	0.028	30.3	0.142	4.334	0.005
45-50	3023	100	0.48	14.5	168	13.9	0.040	0.003	0.038	40.4	0.194	5.859	0.007
		3130					**1.252**	**0.085**			**3.039**	**195.331**	**0.528**

Table – 36C Measured characteristics data of vehicle no. –6 driven on route no. –2 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	4470	0.17	14.4	484	15.0	1.788	0.121	1.818	1939.6	3.297	279.306	0.939
0–5	1042	520	0.15	14.4	468	15.0	0.208	0.014	0.212	225.6	0.338	32.492	0.106
5–10	1250	510	0.23	14.4	392	15.0	0.204	0.014	0.207	221.3	0.509	31.867	0.087
10-15	1568	365	0.23	14.5	288	15.1	0.146	0.010	0.149	159.4	0.367	23.109	0.046
15-20	1778	245	0.24	14.5	257	15.1	0.098	0.007	0.100	107.0	0.257	15.511	0.027
20-25	2104	145	0.31	14.5	196	15.1	0.058	0.004	0.059	63.3	0.196	9.180	0.012
25-30	2454	65	0.35	14.5	188	15.1	0.026	0.002	0.027	28.4	0.099	4.115	0.005
30-35	2664	45	0.41	14.3	178	15.1	0.018	0.001	0.018	19.6	0.081	2.810	0.003
35-40	2790	55	0.43	14.3	171	15.0	0.022	0.001	0.022	23.9	0.103	3.413	0.004
40-45	2889	30	0.47	14.3	169	13.9	0.012	0.001	0.011	12.1	0.057	1.734	0.002
		6450					**2.580**	**0.175**			**5.304**	**403.536**	**1.232**

Table – 37C Measured characteristics data of vehicle no. –1 driven on the route no. –3 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	2110	0.19	12.3	387	15.1	0.844	0.057	0.864	921.3	1.750	113.319	0.357
0–5	907	320	0.19	12.3	413	14.6	0.128	0.009	0.127	135.4	0.257	16.652	0.056
5–10	1087	185	0.67	12.4	382	14.4	0.074	0.005	0.072	77.3	0.518	9.581	0.030
10-15	1378	145	0.41	12.6	285	14.6	0.058	0.004	0.057	61.3	0.252	7.730	0.017
15-20	1554	65	0.39	12.9	253	14.6	0.026	0.002	0.026	27.5	0.107	3.547	0.007
20-25	1842	155	0.59	13.0	252	14.7	0.062	0.004	0.062	66.0	0.389	8.580	0.017
25-30	2029	65	0.45	13.1	315	14.5	0.026	0.002	0.026	27.3	0.123	3.579	0.009
30-35	2289	80	0.35	12.9	332	14.4	0.032	0.002	0.031	33.4	0.117	4.310	0.011
35-40	2429	90	0.34	12.8	325	14.2	0.036	0.002	0.035	37.1	0.126	4.749	0.012
40-45	2643	65	0.35	12.8	282	13.9	0.026	0.002	0.025	26.3	0.092	3.362	0.007
		3280					**1.312**	**0.089**			**3.731**	**175.409**	**0.522**

Table – 38C Measured characteristics data of vehicle no. –1 driven on the route no. –3 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	840	0.19	12.3	387	15.1	0.336	0.023	0.344	366.8	0.697	45.113	0.142
0–5	907	50	0.19	12.3	413	14.6	0.020	0.001	0.020	21.2	0.040	2.602	0.009
5–10	1087	90	0.67	12.4	382	14.4	0.036	0.002	0.035	37.6	0.252	4.661	0.014
10-15	1378	240	0.41	12.6	285	14.6	0.096	0.007	0.095	101.5	0.416	12.794	0.029
15-20	1554	150	0.39	12.9	253	14.6	0.060	0.004	0.059	63.5	0.247	8.186	0.016
20-25	1842	120	0.59	13.0	252	14.7	0.048	0.003	0.048	51.1	0.301	6.642	0.013
25-30	2029	135	0.45	13.1	315	14.5	0.054	0.004	0.053	56.7	0.255	7.434	0.018
30-35	2289	50	0.35	12.9	332	14.4	0.020	0.001	0.020	20.9	0.073	2.694	0.007
35-40	2429	90	0.34	12.8	325	14.2	0.036	0.002	0.035	37.1	0.126	4.749	0.012
40-45	2643	30	0.35	12.8	282	13.9	0.012	0.001	0.011	12.1	0.042	1.552	0.003
45-50	2845	15	0.35	12.8	276	13.4	0.006	0.000	0.005	5.9	0.021	0.750	0.002
		1810					**0.724**	**0.049**			**2.472**	**97.176**	**0.265**

Table – 39C Measured characteristics data of vehicle no. –1 driven on route no. –3 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	2160	0.19	12.3	387	15.1	0.864	0.059	0.885	943.1	1.792	116.004	0.365
0–5	907	210	0.19	12.3	413	14.6	0.084	0.006	0.083	88.8	0.169	10.928	0.037
5–10	1087	190	0.67	12.4	382	14.4	0.076	0.005	0.074	79.4	0.532	9.840	0.030
10-15	1378	120	0.41	12.6	285	14.6	0.048	0.003	0.048	50.8	0.208	6.397	0.014
15-20	1554	90	0.39	12.9	253	14.6	0.036	0.002	0.036	38.1	0.148	4.912	0.010
20-25	1842	145	0.59	13.0	252	14.7	0.058	0.004	0.058	61.7	0.364	8.026	0.016
25-30	2029	65	0.45	13.1	315	14.5	0.026	0.002	0.026	27.3	0.123	3.579	0.009
30-35	2289	50	0.35	12.9	332	14.4	0.020	0.001	0.020	20.9	0.073	2.694	0.007
35-40	2429	80	0.34	12.8	325	14.2	0.032	0.002	0.031	33.0	0.112	4.221	0.011
40-45	2643	30	0.35	12.8	282	13.9	0.012	0.001	0.011	12.1	0.042	1.552	0.003
		3140					**1.256**	**0.085**			**3.564**	**168.153**	**0.501**

Table – 40C Measured characteristics data of vehicle no. –2 driven on the route no. –3 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	712	2110	0.57	13.8	228	15.2	0.844	0.057	0.870	927.0	5.284	127.928	0.211
0–5	1091	320	0.35	14.0	155	15.4	0.128	0.009	0.134	142.3	0.498	19.926	0.022
5–10	1277	185	0.32	13.9	129	15.6	0.074	0.005	0.078	83.3	0.267	11.577	0.011
10-15	1524	145	0.36	14.0	119	15.4	0.058	0.004	0.061	64.5	0.232	9.029	0.008
15-20	1761	65	0.44	14.1	121	15.2	0.026	0.002	0.027	28.6	0.126	4.027	0.003
20-25	2164	155	0.53	14.2	117	15.1	0.062	0.004	0.063	67.7	0.359	9.610	0.008
25-30	2221	65	0.57	14.2	115	15.1	0.026	0.002	0.027	28.4	0.162	4.030	0.003
30-35	2438	80	0.60	14.1	97	15.1	0.032	0.002	0.033	34.9	0.210	4.925	0.003
35-40	2632	90	0.62	14.1	90	15.0	0.036	0.002	0.037	39.1	0.242	5.506	0.004
40-45	2929	65	0.57	14.2	89	15.0	0.026	0.002	0.026	28.2	0.161	4.005	0.003
		3280					**1.312**	**0.089**			**7.539**	**200.563**	**0.276**

Table –41C Measured characteristics data of vehicle no. –2 driven on the route no. –3 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	712	840	0.57	13.8	228	15.2	0.336	0.023	0.346	369.0	2.104	50.929	0.084
0–5	1091	50	0.35	14.0	155	15.4	0.020	0.001	0.021	22.2	0.078	3.113	0.003
5–10	1277	90	0.32	13.9	129	15.6	0.036	0.002	0.038	40.5	0.130	5.632	0.005
10-15	1524	240	0.36	14.0	119	15.4	0.096	0.007	0.100	106.7	0.384	14.944	0.013
15-20	1761	150	0.44	14.1	121	15.2	0.060	0.004	0.062	65.9	0.290	9.292	0.008
20-25	2164	120	0.53	14.2	117	15.1	0.048	0.003	0.049	52.4	0.278	7.440	0.006
25-30	2221	135	0.57	14.2	115	15.1	0.054	0.004	0.055	58.9	0.336	8.370	0.007
30-35	2438	50	0.60	14.1	97	15.1	0.020	0.001	0.020	21.8	0.131	3.078	0.002
35-40	2632	90	0.62	14.1	90	15.0	0.036	0.002	0.037	39.1	0.242	5.506	0.004
40-45	2929	30	0.57	14.2	89	15.0	0.012	0.001	0.012	13.0	0.074	1.848	0.001
45-50	3023	15	0.54	14.4	87	14.9	0.006	0.000	0.006	6.5	0.035	0.931	0.001
		1810					**0.724**	**0.049**			**4.081**	**111.085**	**0.134**

Table – 42C Measured characteristics data of vehicle no. –2 driven on the route no. –3 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	712	2160	0.57	13.8	228	15.2	0.864	0.059	0.890	949.0	5.409	130.960	0.216
0–5	1091	210	0.35	14.0	155	15.4	0.084	0.006	0.088	93.4	0.327	13.076	0.014
5–10	1277	190	0.32	13.9	129	15.6	0.076	0.005	0.080	85.5	0.274	11.890	0.011
10-15	1524	120	0.36	14.0	119	15.4	0.048	0.003	0.050	53.4	0.192	7.472	0.006
15-20	1761	90	0.44	14.1	121	15.2	0.036	0.002	0.037	39.5	0.174	5.575	0.005
20-25	2164	145	0.53	14.2	117	15.1	0.058	0.004	0.059	63.3	0.336	8.990	0.007
25-30	2221	65	0.57	14.2	115	15.1	0.026	0.002	0.027	28.4	0.162	4.030	0.003
30-35	2438	50	0.60	14.1	97	15.1	0.020	0.001	0.020	21.8	0.131	3.078	0.002
35-40	2632	80	0.62	14.1	90	15.0	0.032	0.002	0.033	34.7	0.215	4.895	0.003
40-45	2929	30	0.57	14.2	89	15.0	0.012	0.001	0.012	13.0	0.074	1.848	0.001
		3140					**1.256**	**0.085**			**7.294**	**191.815**	**0.270**

Table – 43C Measured characteristics data of vehicle no. –3 driven on the route no. –3 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	858	2110	4.05	10.7	1063	14.0	0.844	0.057	0.801	858.3	34.763	91.843	0.912
0–5	1027	320	3.95	10.6	1329	14.0	0.128	0.009	0.121	130.2	5.142	13.799	0.173
5–10	1231	185	4.39	10.3	1401	13.7	0.074	0.005	0.069	73.8	3.238	7.597	0.103
10-15	1554	145	6.78	9.0	1460	12.6	0.058	0.004	0.050	53.5	3.626	4.813	0.078
15-20	1728	65	7.21	9.2	1181	12.2	0.026	0.002	0.022	23.3	1.678	2.141	0.027
20-25	2198	155	6.94	9.0	1304	12.4	0.062	0.004	0.052	56.3	3.909	5.070	0.073
25-30	2454	65	7.10	9.1	1245	12.4	0.026	0.002	0.022	23.6	1.677	2.150	0.029
30-35	2691	80	7.32	9.0	1146	12.2	0.032	0.002	0.026	28.6	2.096	2.577	0.033
35-40	2790	90	7.50	9.0	1103	12.1	0.036	0.002	0.030	32.0	2.398	2.878	0.035
40-45	2889	65	7.93	9.0	1049	12.0	0.026	0.002	0.021	22.9	1.817	2.062	0.024
		3280					**1.312**	**0.089**			**60.344**	**134.929**	**1.489**

Table – 44C Measured characteristics data of vehicle no. –3 driven on the route no. –3 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	858	840	4.05	10.7	1063	14.0	0.336	0.023	0.319	341.7	13.839	36.563	0.363
0–5	1027	50	3.95	10.6	1329	14.0	0.020	0.001	0.019	20.3	0.803	2.156	0.027
5–10	1231	90	4.39	10.3	1401	13.7	0.036	0.002	0.033	35.9	1.575	3.696	0.050
10-15	1554	240	6.78	9.0	1460	12.6	0.096	0.007	0.082	88.5	6.002	7.967	0.129
15-20	1728	150	7.21	9.2	1181	12.2	0.060	0.004	0.050	53.7	3.872	4.940	0.063
20-25	2198	120	6.94	9.0	1304	12.4	0.048	0.003	0.040	43.6	3.026	3.925	0.057
25-30	2454	135	7.10	9.1	1245	12.4	0.054	0.004	0.045	49.1	3.483	4.464	0.061
30-35	2691	50	7.32	9.0	1146	12.2	0.020	0.002	0.017	17.9	1.310	1.611	0.021
35-40	2790	90	7.50	9.0	1103	12.1	0.036	0.002	0.030	32.0	2.398	2.878	0.035
40-45	2889	30	7.93	9.0	1049	12.0	0.012	0.001	0.010	10.6	0.839	0.952	0.011
45-50	3012	15	7.90	9.0	1040	12.0	0.006	0.000	0.005	5.3	0.418	0.476	0.006
		1810					**0.724**	**0.049**			**37.566**	**69.628**	**0.824**

Table – 45C Measured characteristics data of vehicle no. –3 driven on the route no. –3 at evening peak hour (1645hrs).

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	858	2160	4.05	10.7	1063	14.0	0.864	0.059	0.820	878.7	35.587	94.020	0.934
0–5	1027	210	3.95	10.6	1329	14.0	0.084	0.006	0.080	85.4	3.374	9.055	0.114
5–10	1231	190	4.39	10.3	1401	13.7	0.076	0.005	0.071	75.7	3.325	7.802	0.106
10-15	1554	120	6.78	9.0	1460	12.6	0.048	0.003	0.041	44.3	3.001	3.983	0.065
15-20	1728	90	7.21	9.2	1181	12.2	0.036	0.002	0.030	32.2	2.323	2.964	0.038
20-25	2198	145	6.94	9.0	1304	12.4	0.058	0.004	0.049	52.7	3.657	4.742	0.069
25-30	2454	65	7.10	9.1	1245	12.4	0.026	0.002	0.022	23.6	1.677	2.150	0.029
30-35	2691	50	7.32	9.0	1146	12.2	0.020	0.001	0.017	17.9	1.310	1.611	0.021
35-40	2790	80	7.50	9.0	1103	12.1	0.032	0.002	0.026	28.4	2.132	2.558	0.031
40-45	2889	30	7.93	9.0	1049	12.0	0.012	0.001	0.010	10.6	0.839	0.952	0.011
		3140	**7.90**	**9.0**			**1.256**	**0.085**			**57.225**	**129.837**	**1.417**

Table – 46C Measured characteristics data of vehicle no. –4 driven on the route no. –3 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	945	2110	6.10	10.6	408	12.2	0.844	0.057	0.698	755.3	46.076	80.067	0.308
0–5	1025	320	5.51	10.4	407	12.8	0.128	0.009	0.111	119.8	6.599	12.455	0.049
5–10	1251	185	6.06	10.7	417	12.4	0.074	0.005	0.062	67.2	4.074	7.194	0.028
10-15	1551	145	5.93	10.8	428	12.4	0.058	0.004	0.049	52.7	3.125	5.691	0.023
15-20	1727	65	4.96	11.3	387	12.8	0.026	0.002	0.023	24.3	1.207	2.749	0.009
20-25	2059	155	4.47	11.5	335	13.1	0.062	0.004	0.055	59.3	2.649	6.816	0.020
25-30	2236	65	4.62	11.6	320	13.1	0.026	0.002	0.023	24.9	1.148	2.883	0.008
30-35	2425	80	5.02	11.4	307	12.9	0.032	0.002	0.028	30.2	1.514	3.438	0.009
35-40	2608	90	4.83	11.5	285	12.9	0.036	0.002	0.031	33.9	1.639	3.902	0.010
40-45	2845	65	5.17	11.5	257	12.8	0.026	0.002	0.023	24.3	1.258	2.798	0.006
		3280					**1.312**	**0.089**			**69.289**	**127.992**	**0.470**

Table –47C Measured characteristics data of vehicle no. –4 driven on the route no. –3 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	712	2160	0.57	13.8	228	15.2	0.864	0.059	0.890	949.0	5.409	130.960	0.216
0–5	1091	210	0.35	14.0	155	15.4	0.084	0.006	0.088	93.4	0.327	13.076	0.014
5–10	1277	190	0.32	13.9	129	15.6	0.076	0.005	0.080	85.5	0.274	11.890	0.011
10-15	1524	120	0.36	14.0	119	15.4	0.048	0.003	0.050	53.4	0.192	7.472	0.006
15-20	1761	90	0.44	14.1	121	15.2	0.036	0.002	0.037	39.5	0.174	5.575	0.005
20-25	2164	145	0.53	14.2	117	15.1	0.058	0.004	0.059	63.3	0.336	8.990	0.007
25-30	2221	65	0.57	14.2	115	15.1	0.026	0.002	0.027	28.4	0.162	4.030	0.003
30-35	2438	50	0.60	14.1	97	15.1	0.020	0.001	0.020	21.8	0.131	3.078	0.002
35-40	2632	80	0.62	14.1	90	15.0	0.032	0.002	0.033	34.7	0.215	4.895	0.003
40-45	2929	30	0.57	14.2	89	15.0	0.012	0.001	0.012	13.0	0.074	1.848	0.001
		3140					**1.256**	**0.085**			**7.294**	**191.815**	**0.270**

Table –48C Measured characteristics data of vehicle no. –4 driven on the route no. –3 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	656	2110	0.54	13.3	355	15.6	0.844	0.057	0.893	949.9	5.129	126.337	0.337
0–5	1075	320	0.74	13.6	255	15.2	0.128	0.009	0.132	140.6	1.040	19.120	0.036
5–10	1201	185	0.88	13.6	202	15.1	0.074	0.005	0.076	80.8	0.711	10.986	0.016
10-15	1501	145	0.75	13.7	185	15.2	0.058	0.004	0.060	63.7	0.478	8.728	0.012
15-20	1723	65	0.68	13.7	159	15.1	0.026	0.002	0.027	28.4	0.193	3.888	0.005
20-25	2009	155	0.80	13.8	138	15.1	0.062	0.004	0.063	67.7	0.541	9.340	0.009
25-30	2221	65	0.81	13.8	132	15.1	0.026	0.002	0.027	28.4	0.230	3.917	0.004
30-35	2438	80	0.83	13.8	105	15.1	0.032	0.002	0.033	34.9	0.290	4.820	0.004
35-40	2632	90	0.80	13.8	98	15.1	0.036	0.002	0.037	39.3	0.314	5.423	0.004
40-45	2929	65	0.76	13.9	101	15.0	0.026	0.002	0.026	28.2	0.214	3.920	0.003
		3280					**1.312**	**0.089**			**9.141**	**196.479**	**0.429**

Table –49C Measured characteristics data of vehicle no. –5 driven on the route no. –3 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	656	2160	0.54	13.3	355	15.6	0.864	0.059	0.914	972.4	5.251	129.331	0.345
0–5	1075	210	0.74	13.6	255	15.2	0.084	0.006	0.087	92.3	0.683	12.548	0.024
5–10	1201	190	0.88	13.6	202	15.1	0.076	0.005	0.078	83.0	0.730	11.283	0.017
10-15	1501	120	0.75	13.7	185	15.2	0.048	0.003	0.049	52.7	0.395	7.223	0.010
15-20	1723	90	0.68	13.7	159	15.1	0.036	0.002	0.037	39.3	0.267	5.384	0.006
20-25	2009	145	0.80	13.8	138	15.1	0.058	0.004	0.059	63.3	0.506	8.737	0.009
25-30	2221	65	0.81	13.8	132	15.1	0.026	0.002	0.027	28.4	0.230	3.917	0.004
30-35	2438	50	0.83	13.8	105	15.1	0.020	0.001	0.020	21.8	0.181	3.013	0.002
35-40	2632	80	0.80	13.8	98	15.1	0.032	0.002	0.033	34.9	0.279	4.820	0.003
40-45	2929	30	0.76	13.9	101	15.0	0.012	0.001	0.012	13.0	0.099	1.809	0.001
		3140					**1.256**	**0.085**			**8.622**	**188.064**	**0.421**

Table –50C Measured characteristics data of vehicle no. –5 driven on the route no. –3 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	*Engine Speed (rpm)*	*Driving Time (sec)*	*CO (%)*	*CO_2 (%)*	*HC (ppm)*	*AFR*	*Fuel Cons. (ltr)*	*Fuel Mass (kg)*	*Air Mass (kg)*	*AF Mass (kg)*	*CO (gm)*	*CO_2 (gm)*	*HC (gm)*
0	656	840	0.54	13.3	355	15.6	0.336	0.023	0.355	378.2	2.042	50.295	0.134
0–5	1075	50	0.74	13.6	255	15.2	0.020	0.001	0.021	22.0	0.163	2.988	0.006
5–10	1201	90	0.88	13.6	202	15.1	0.036	0.002	0.037	39.3	0.346	5.344	0.008
10-15	1501	240	0.75	13.7	185	15.2	0.096	0.007	0.099	105.4	0.791	14.446	0.020
15-20	1723	150	0.68	13.7	159	15.1	0.060	0.004	0.061	65.5	0.445	8.973	0.010
20-25	2009	120	0.80	13.8	138	15.1	0.048	0.003	0.049	52.4	0.419	7.231	0.007
25-30	2221	135	0.81	13.8	132	15.1	0.054	0.004	0.055	58.9	0.477	8.134	0.008
30-35	2438	50	0.83	13.8	105	15.1	0.020	0.001	0.020	21.8	0.181	3.013	0.002
35-40	2632	90	0.80	13.8	98	15.1	0.036	0.002	0.037	39.3	0.314	5.423	0.004
40-45	2929	30	0.76	13.9	101	15.0	0.012	0.001	0.012	13.0	0.099	1.809	0.001
45-50	3032	15	0.75	13.9	105	15.0	0.006	0.000	0.006	6.5	0.049	0.905	0.001
		1810					**0.724**	**0.049**			**5.327**	**108.561**	**0.201**

Table –51C Measured characteristics data of vehicle no. –5 driven on the route no. –3 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	713	2160	0.19	12.3	387	15.1	0.864	0.059	0.885	943.1	1.792	116.004	0.365
0–5	907	210	0.19	12.3	413	14.6	0.084	0.006	0.083	88.8	0.169	10.928	0.037
5–10	1087	190	0.67	12.4	382	14.4	0.076	0.005	0.074	79.4	0.532	9.840	0.030
10-15	1378	120	0.41	12.6	285	14.6	0.048	0.003	0.048	50.8	0.208	6.397	0.014
15-20	1554	90	0.39	12.9	253	14.6	0.036	0.002	0.036	38.1	0.148	4.912	0.010
20-25	1842	145	0.59	13.0	252	14.7	0.058	0.004	0.058	61.7	0.364	8.026	0.016
25-30	2029	65	0.45	13.1	315	14.5	0.026	0.002	0.026	27.3	0.123	3.579	0.009
30-35	2289	50	0.35	12.9	332	14.4	0.020	0.001	0.020	20.9	0.073	2.694	0.007
35-40	2429	80	0.34	12.8	325	14.2	0.032	0.002	0.031	33.0	0.112	4.221	0.011
40-45	2643	30	0.35	12.8	282	13.9	0.012	0.001	0.011	12.1	0.042	1.552	0.003
		3140					**1.256**	**0.085**			**3.564**	**168.153**	**0.501**

Table –52C Measured characteristics data of vehicle no. –6 driven on the route no. –3 at morning peak hour (0900 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	2110	0.17	14.4	484	15.0	0.844	0.057	0.858	915.6	1.556	131.842	0.443
0–5	1042	320	0.15	14.4	468	15.0	0.128	0.009	0.130	138.9	0.208	19.995	0.065
5–10	1250	185	0.23	14.4	392	15.0	0.074	0.005	0.075	80.3	0.185	11.560	0.031
10-15	1568	145	0.23	14.5	288	15.1	0.058	0.004	0.059	63.3	0.146	9.180	0.018
15-20	1778	65	0.24	14.5	257	15.1	0.026	0.002	0.027	28.4	0.068	4.115	0.007
20-25	2104	155	0.31	14.5	196	15.1	0.062	0.004	0.063	67.7	0.210	9.813	0.013
25-30	2454	65	0.35	14.5	188	15.1	0.026	0.002	0.027	28.4	0.099	4.115	0.005
30-35	2664	80	0.41	14.3	178	15.1	0.032	0.002	0.033	34.9	0.143	4.995	0.006
35-40	2790	90	0.43	14.3	171	15.0	0.036	0.002	0.037	39.1	0.168	5.585	0.007
40-45	2889	65	0.47	14.3	169	13.9	0.026	0.002	0.025	26.3	0.123	3.756	0.004
		3280					**1.312**	**0.089**			**2.907**	**204.957**	**0.601**

Table –53C Measured characteristics data of vehicle no. –6 driven on route no. –3 at noon off- peak hour (1245 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	840	0.17	14.4	484	15.0	0.336	0.023	0.342	364.5	0.620	52.487	0.176
0–5	1042	50	0.15	14.4	468	15.0	0.020	0.001	0.020	21.7	0.033	3.124	0.010
5–10	1250	90	0.23	14.4	392	15.0	0.036	0.002	0.037	39.1	0.090	5.624	0.015
10-15	1568	240	0.23	14.5	288	15.1	0.096	0.007	0.098	104.8	0.241	15.195	0.030
15-20	1778	150	0.24	14.5	257	15.1	0.060	0.004	0.061	65.5	0.157	9.497	0.017
20-25	2104	120	0.31	14.5	196	15.1	0.048	0.003	0.049	52.4	0.162	7.597	0.010
25-30	2454	135	0.35	14.5	188	15.1	0.054	0.004	0.055	58.9	0.206	8.547	0.011
30-35	2664	50	0.41	14.3	178	15.1	0.020	0.001	0.020	21.8	0.090	3.122	0.004
35-40	2790	90	0.43	14.3	171	15.0	0.036	0.002	0.037	39.1	0.168	5.585	0.007
40-45	2889	30	0.47	14.3	169	13.9	0.012	0.001	0.011	12.1	0.057	1.734	0.002
45-50	3023	15	0.48	14.5	168	13.9	0.006	0.000	0.006	6.1	0.029	0.879	0.001
		1810					**0.724**	**0.049**			**1.852**	**113.390**	**0.284**

Table –54C Measured characteristics data of vehicle no. –6 driven on route no. –3 at evening peak hour (1645 hrs)

Vehicle speed (km/hr)	Engine Speed (rpm)	Driving Time (sec)	CO (%)	CO_2 (%)	HC (ppm)	AFR	Fuel Cons. (ltr)	Fuel Mass (kg)	Air Mass (kg)	AF Mass (kg)	CO (gm)	CO_2 (gm)	HC (gm)
0	697	2160	0.17	14.4	484	15.0	0.864	0.059	0.879	937.3	1.593	134.967	0.454
0–5	1042	210	0.15	14.4	468	15.0	0.084	0.006	0.085	91.1	0.137	13.122	0.043
5–10	1250	190	0.23	14.4	392	15.0	0.076	0.005	0.077	82.4	0.190	11.872	0.032
10-15	1568	120	0.23	14.5	288	15.1	0.048	0.003	0.049	52.4	0.121	7.597	0.015
15-20	1778	90	0.24	14.5	257	15.1	0.036	0.002	0.037	39.3	0.094	5.698	0.010
20-25	2104	145	0.31	14.5	196	15.1	0.058	0.004	0.059	63.3	0.196	9.180	0.012
25-30	2454	65	0.35	14.5	188	15.1	0.026	0.002	0.027	28.4	0.099	4.115	0.005
30-35	2664	50	0.41	14.3	178	15.1	0.020	0.001	0.020	21.8	0.090	3.122	0.004
35-40	2790	80	0.43	14.3	171	15.0	0.032	0.002	0.033	34.7	0.149	4.964	0.006
40-45	2889	30	0.47	14.3	169	13.9	0.012	0.001	0.011	12.1	0.057	1.734	0.002
		3140					**1.256**	**0.085**			**2.726**	**196.371**	**0.583**