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ENERGY AND ENVIRONMENTAL IMPLICATIONS OF ALTERNATIVE TRANSPORT OPTIONS: THE CASE OF KATHMANDU, NEPAL

by

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A thesis submitted in partial fulfillment of the requirements for the degree of Master of Engineering.

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Abstract

Kathmandu Valley, the capital city of Nepal, is facing the vehicular air pollution problems in the recent years. Transport sector contributed about 31 thousand tons of pollutants in 1996. Vehicular pollutants are expected to reach 41 thousand tons in 2010 and 53 thousand tons in year 2020. This study analyzes the different vehicle options and emission control devices & measures in order to assess the emission reduction potential from the transport sector in the Valley. Trolley bus, electric 3-wheeler, electric minibus and LPG 3-wheeler are alternative vehicular options examined here. The economics and emission mitigating potential of the emission control devices and measures such as magnetizer, unleaded gasoline, catalytic converter, and inspection and maintenance program are also looked into. Fuel quality, emission standards, and the selection of appropriate vehicle types are also discussed in this study.

This study reveals that the driving characteristics and present electricity generation capacity favour the electric vehicle in the Valley. However, the present development trends and the likely number of future electric vehicles may not significantly contribute to mitigate the vehicular air pollution problems. There would be only about 0.50 per cent reduction of total pollutants from the transport sector in 2000 and likewise 1.2 per cent in 2020. Rather emission mitigation through the application of emission control devices and measures seem to be more effective. There would be about 884 tons of CO, 119 tons of HC, 38 tons of NOx and 1.5 tons of Pb reduction in 2000, if all new cars and taxis were made mandatory for using unleaded gasoline and catalytic converter. The same approach would reduce about 8706 tons of CO, 1177 tons of HC, 382 tons of NOx and 2.5 tons of Pb in year 2020. The national emission standards of smoke for diesel vehicles and carbon monoxide for gasoline vehicles could also be maintained through the inspection and maintenance program.

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List of Abbreviations

ABB	Asea Brown Boveri
AC	Alternative Current
AFC	Average Fuel Consumption
AIT	Asian Institute of Technology
BHEL	Bharat Heavy Electric Limited
BZTMO	Bagmati Zonal Transport Management Office, Nepal
CARB	California Air Research Board
CBS	Central Bureau of Statistics
CC	Catalytic Converter
CD	Corps de Diplomat
CERI	Canadian Energy Research Institute
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CPA	Cost of Pollution Abatement
CPR	Cost of Pollution Reduction
DAQ	Desired Air Quality
DC	Direct Current
DOD	Depth of Discharge
DOR	Department of Road
DOTM	Department of Transport Management, Nepal
ECD	Emission Control Device
ECD/M	Emission Control Device and Measure
EF	Emission Factors
ENPHO	Environment and Public Health Organization , Nepal
EPA	Environment Protection Agency
EPC	Environment Protection Council
ESC	Economic Service Center
ESCAP	Economic and Social Commission for Asia and Pacific
EV	Electrical Vehicle
EVCO	Electric Vehicle Company
FY	Fiscal Year
GDP	Gross Domestic Products
GHG	Green House Gas
GJ	Gigajoule
GRI	Global Resources Institute
HC	Hydro Carbon
HMG	His Majesty's Government
HP	Horse Power
HSU	Hartridge Smoke Unit
I/M	Inspection and Maintenance
IEA	International Energy Agency
IF	Integrated Forum

List of Abbreviations (Continued)

INPS	Integrated Nepal's Power System
IOC	Indian Oil Corporation
IUCN	International Union of Natural Conservation
JICA	Japan International Cooperation Agency
kl	Kiloliter
km	kilometer
KV	Kilovolt
KVVECP	Kathmandu Valley Vehicular Emission Control Project
kW	Kilowatt
kWh	Kilowatt Hour
LC	Levelized Cost
LPG	Liquefied Petroleum Gas
MOF	Ministry of Finance
MOPE	Ministry of Population and Environment
MW	Megawatt
N_2O	Nitrous Oxide
NEA	Nepal Electricity Authority
NESS	Nepal Environmental and Scientific Service (P) Ltd.
NEVI	Nepal Electric Vehicle Industry (P) Ltd.
NGO	Non Governmental Organization
NOC	Nepal Oil Corporation
NOx	Nitrogen Oxide
NPC	National Planning Commission
NPV	Net Present Value
NRs	Nepalese Rupees
NZERDC	New Zealand Energy Research and Development Committee
OECD	Organization of Economic Cooperation and Development
O&M	Operation and Maintenance
ONEB	Office of National Environment Board
PAQ	Present Air Quality
Pb	Lead
PM10	Particulate Matter Less than 10 Micro Size
ppm	Parts per Million
REDP	Regional Energy Development Program
RONAST	Royal Nepal Academy of Science and Technology
SFC	Specific Fuel Consumption
SO_2	Sulfur Dioxide
SPSS	Statistical Package for Social Science
TKP	The Kathmandu Post
TRN	The Rising Nepal
TSP	Total Suspended Particles
TU	Tribhuvan University
ULG	Unleaded Gasoline

List of Abbreviations (Continued)

UN	United Nations
UNDP	United Nations Development Program
URBAIR	Urban Air Project
US	United States
US-AEP	United States-Asia Environmental Partnership
USAID	United States Agency for International Development
vkm	Vehicle kilometer
VTP	Valley Traffic Police
WECS	Water and Energy Commission Secretariat
WHO	World Health Organization

Chapter 1

Introduction

1.1 Background

Air pollution is a growing urban problem affecting millions of people in different parts of the world. Kathmandu Valley, the capital city of Nepal, is not freed from the problem of air pollution. As the population of the Valley has dramatically increased over the last decade, the quality of environment has drastically deteriorated with the increasing number of motor vehicles.

Air pollution, caused by the vehicular traffic in cities, has detrimental effects on the economy of the country and human health. It imposes a significant amount of social and economic costs. The vast majority of vehicles in the Valley are powered by internal combustion engines using gasoline as a fuel. One of the major drawbacks of this fuel is the air pollutants that are emitted into the atmosphere. In recent years alternative fuels have attracted attention as a possible means of reducing local pollution in many parts of the world. Such initiatives have also been started in Kathmandu to lessen the burden of air pollution. Safa (Clean) electrical tempo and the LPG-run Tuk-Tuk are the examples of such initiative initiated in the Valley.

Emission control devices and measures (ECD/M) have been playing a remarkable role on vehicular emission control in many parts of the World. However, ECD/M are recent intervention in order to lessen the burden of vehicular emissions in the Valley.

With all these backgrounds, this study intends to study the energy, economic and environmental implications of the alternative transport options and ECD/M in the case of Kathmandu Valley.

1.2 Problem Statement and Rationale

The major problem related with the energy use in the Kathmandu Valley is the air pollution. A World Bank -UNDP project shows that the health of Kathmandu's residents is under threat (TKP, May 1997). It estimated the total health damage in terms of monetary unit which is equivalent to a whopping 210 million rupees (3.7 million US $) in a year. Government and the people in the Valley have shown their keen interest to mitigate these problems making the Valley clean in terms of air pollution.

One important approach for reducing the air pollution in the Valley is the introduction of alternative form of transport vehicles. Many people are of the opinion that the Kathmandu Valley is specially well suited for electric vehicles and could become a model for the rest of the world. Similarly, alternate fuel vehicles, such as those using LPG, are also suggested to be a substitute for existing petroleum fuel vehicles for reducing air pollution in cost-effective manner in the Valley. Pollution reduction objectives can also be successfully achieved by introducing or applying emission control devices and measures (ECD/M).

There are many type of vehicles already introduced in the Valley. Their operational cost, cost-effectiveness and pollution mitigating potential need to be studied in a depth for developing appropriate responses to the air pollution problem. Similarly the effectiveness of the pollution control measures and devices need to be looked into. Such assessments will be of great interest to the policy makers for formulating the policies and plans. This study provides enough useful information, as well to the general people to make decision on the vehicle purchase for their utilization.

1.3 Objectives

The specific objectives of the study are:

- to forecast the demand for passenger transport services by type of vehicle,
- to analyze the economics of selected vehicular options, and
- to assess the pollution reduction potential, impacts on air quality and economics of selected vehicles and emission control options.

1.4 Scope and Limitations

Vehicle forecast is carried out upto the year 2020. Estimation of emissions includes the both local and global warming pollutants. This study applies the simple "Linear Rollback' approach for investigating the impacts on air quality from the vehicular exhaust emissions. Life-cycle costs of the vehicles are calculated from both the national and an individual perspective.

The study examines the economics and emission implications of electrical and LPG vehicles as an alternative mode of transport in Kathmandu Valley. In electrical vehicles, main focus is placed on the electric bus and converted three-wheelers. In the case of LPG, only three-wheelers are considered in this study.

The emission control devices and measures (ECD/M) include the magnetizer, unleaded gasoline, catalytic converter and inspection and maintenance (I/M) program.

1.5 Organization of the Study

The study report comprises the 11 chapters. Chapter 1 contains the introductory part of the study. Chapter 2 introduces the profile of the Kathmandu Valley. Some relevant literature are reviewed in Chapter 3. Chapter 4 explains the methodologies adopted for the study. Transport characteristic and the results of vehicle forecast are given in Chapter 5. Chapter 6 presents the results of vehicular emissions and their impacts on air quality. Economics of the vehicle operations are included in Chapter 7. Chapter 8 and 9 concentrate on Electric vehicle and emission control devices and measures (ECD/M). Major issues and policy options are included in Chapter 10. Chapter 11 concludes the findings of the study and prepares a list of recommendations.

Chapter 2

Profile of Kathmandu Valley

2.1 General

Kathmandu is the capital city of the Kingdom of Nepal situated between 28°32'13° north to 28°49'0° north latitude and 85°11'31" to 85°31'38" east longitude. It is 26 km in east-west direction and 20 km wide in north-south direction. It has a population of about 1.1 millions, according to the national census 1991. The population growth rate of the valley is 3.38 per cent -- above the national average of 2.6 per cent. Kathmandu Valley comprises three administrative districts, namely Kathmandu, Lalitpur and Bhaktapur. The Valley is surrounded by all its four directions by the hills which range from 2100 m to 3132 m in altitude. It is situated in 1350 m above the mean sea level. The average rainfall of the valley is about 1300 mm.

2.2 Economic Role

The main activity in the Valley is so called primary industry which includes agriculture, forestry and fishing and contributes for 75 % employment. Other sectors account for very small percentages on employment. Commercial and manufacturing sectors contribute five per cent and two per cent employment respectively.

The share of agriculture on the national economy is only four per cent. However, the shares of the industries are very high, 20.6 per cent from mining, 18.8 per cent from manufacturing, 28.7 per cent from construction, 17.3 per cent from commercial, 27 per cent from transport and communication and 35 per cent from the financial services (JICA, 1992). Analyzing the above facts and figures, Valley alone contributes about 13 per cent on the national economy. The study conducted by the CBS (1996) came with the similar type of result on the per capita consumption of the Valley resident. It is NRs. 14345 per year for the Kathmandu Valley compared to NRs. 6802 per year of national average.

2.3 Population Growth

At the time of the 1952 census, only three per cent of the population were used to live in urban areas. By 1971, it was slightly over nine per cent. During the decade 1981-1991 the urban population rose by 15 per cent (EPC, 1993). Urbanization in the Valley commenced in mid 1950s and it peaked up between 1971 and 1991. The period is coincided with rapid industrial and institutional growth.

Valley population has gone up from 0.411 million in 1952/42 to 1.545 million in 1994, about 67 per cent of which are living in urban areas and the rest 33 per cent in rural areas (Shah, 1995). The population of the Valley was 585.788 according to the population census in

1971 and it was 1,068,475 in 1991 -- at an annual increase rate of 2.5% per annum (CBS, 1995). Likewise, about six per cent of the total population of Nepal reside in the Valley and it accommodates about 35% of the total urban population of the country.

2.4 Road Transport and Vehicle Types

Development of road transport started in the late 1950s in Nepal. The total length of the road transport up to 1994 was 732 km., of which 466 km was black topped, 224 km graveled and 152 km earthen in the Valley. The total length of the road transport in the country was 9534 km in 1994 (Road Statistics, 1995).

The total number of vehicles in the Valley up to the period of 1996 was 106351, in which the Bus/Minibuses are 2841, Trucks 4618, Cars/Jeeps 28131, Tempos 3866, Motorcycles/ Scooters 61614 and the Tractors were 1674. The average growth rate of the road vehicle is about 13 per cent in the Valley (DOTM, 1997). The number of registered road vehicles increased by close to 100 per cent over the last decade from 1971 to 1991 (Larsen et al., 1995).

The vehicle types in the Kathmandu Valley can be categorized into the following types.

1. Passenger cars and jeeps powered by 4-stoke gasoline engines.
2. Two and three wheelers powered mostly by small 2-stoke gasoline engines.
3. Buses, trucks, and light diesel commercial vehicles powered by 4-stoke diesel engine.

Apart from these vehicles, there are some other types of vehicles which are plying in the Kathmandu valley. These are the electric vehicles -- locally known as the Safa (Clean) Tempo, LPG vehicles, and electric Trolley bus. For the past few years, cars and jeeps - - powered by diesel engines -- are also running in the Kathmandu Valley. But their number is relatively small. Some of the three-wheelers are powered by diesel oil.

2.5 Fossil Fuel Use

All the petroleum product requirement of the country have to be imported. The petroleum consumption in the nation was 466,749 kiloliters in fiscal year 1993/94 and 516,331 kiloliters in fiscal year 1994/95 (MOF, 1995). Transport sector consumes about 300 million liters of petroleum products per annum in Nepal. Nepal Oil Corporation (NOC) -- the government authority responsible for supplying petroleum products in the country -- supplied 125 kiloliter of kerosene and 100 kiloliter of diesel daily in Kathmandu Valley (TRN, 1993; cited in Malla, 1993). Almost half of the country's total fossil-fuel imports were consumed in Kathmandu Valley in 1993 (Shrestha and Malla, 1996). In fiscal year 1995/96, NOC sold 41,191 kiloliter motor gasoline and 250,504 kiloliter high speed diesel out of which about 35,000 kiloliter of motor gasoline and 52,530 kiloliter of high speed diesel was consumed in the Kathmandu Valley (Khadka, 1996).

The sectoral share of fossil fuel consumption in the Kathmandu Valley was 35..5 per cent in transport sector whereas the industrial sector consumed 34.8 per cent, household sector 28.6 per cent and 1.1 per cent in the commercial sector (Shrestha and Mall, 1996). Share of diesel among the total petroleum products was accounted for 44.0 per cent, kerosene 35.0 per cent , aviation fuel 7.2 per cent , gasoline 6.7 per cent and other petroleum products were 7.1 per cent in the fiscal year 1994/95 (MOF, 1995).

2.6 Air Pollution and Health Impacts

Effects of air pollution on human health are not precisely known in the Valley. However, there are some facts which hint the extent of the impact of air pollution. There is a high prevalence rate of chronic bronchitis in the Valley. 14.4 per cent in men and 15.2 per cent in women aged 20 and above. There is also high rate of asthma. even children are severely affected. Almost every alternate household has an asthma patient (Shah, 1995). It is further reported that about 38 per cent of the children admitted to the Kanti Children Hospital are infected with acute respiratory infectious disease.

The URBAIR report estimates that air pollution causes approximately 85 premature deaths, 1.5 million days in which people experience respiratory problems and 475,000 restricted activity days due to pollution related illness with estimated damage costs of NRs. 210 million (3.7 million US $) a year (TKP, 1997b).

2.7 Alternative Fuel Vehicle Program

There are three types of vehicles operating on fuels other than gasoline in Kathmandu Valley. These are trolley bus operating on electricity, Safa tempo operating on electrically charged battery and Tuk-Tuk operating on LPG gas. Trolley buses have been operating in the Valley for 23 years, whereas the Safa tempos have been running in the street of the Valley for the last three years. Tuk-tuks are relatively newer and have been operating only for last six month.

Chapter 3

Literature Review

3.1 Pollution and Air Quality in Kathmandu Valley

There are a few studies conducted in Kathmandu Valley on air pollution related issues. Industry and transport are the major sectors which are responsible for air pollution in the Valley. Shrestha and Malla (1996) mentioned that in many parts of the Valley, TSPs concentrations exceeded WHO standard and were comparable with those in Mexico city -- with an average of 100 to 500 microgram per cubic meter (ug/m^3) in 1992. They further mentioned that the level of carbon monoxide, sulfur dioxide and oxides of nitrogen were lower than the standard set by WHO. Similar types of conclusion were also drawn by Rajbahak and Joshi (1993) and Larsen et al. (1995) in their respective studies. Per capita emission of TSP in the Valley was 5.47 kg while it was 4.49 kg in Bombay, 0.34 kg in Buenos Aires and 4.18 kg in Sao Paulo. The emission densities of TSPs, CO, and NOx were 21.5, 130.0 and 7.3 ton/km^2 in the Valley respectively, whereas they were 18.0, 118.0 and 7.0 ton/km^2 in Mexico city respectively (Shrestha and Malla, 1996). The PM_{10} level is also found higher than the WHO guidelines in the many locations of the Kathmandu Valley (Larsen et al., 1995).

Shrestha and Malla (1996) estimated the total emission for the year 2013 under the business as usual scenario and came out with the finding that the emission level would be about five times higher than the total emission level of 1993. About two thirds of these increased emission will come from the transport sector.

The Kathmandu Valley Vehicular Emission Control Project (KVVECP,1993) revealed that the level of TSPs and PM_{10} exceeded the WHO standard of 120 and 70 microgram per square meter in the commercial areas, both at the heavy and the low traffic areas. Even the industrial and residential areas have higher TSPs and PM_{10} concentrations than that of WHO standard. The KVVECP study measured the levels of NO_2 and SO_2 and were found within the WHO limits in all areas of the Valley. Ambient air quality of T.U. site (south-western part with less vehicle concentration) found to be within the standard set by WHO for all pollutants -- TSP, PM_{10}, NO_2 and SO_2.

Devkota in this study (1993) indicated the maximum concentration of CO was found in road side, followed by commercial and residential areas. The value of CO concentrations for these areas were 10 ppm for the road sides, 7.5 ppm for the commercial areas and less than five for the residential areas. In Nepal, gasoline used in the transport sector is of 87 octane rating which contains about 0.58 gm/liter of lead (Sharma and Upadhyaya, 1995). The lead level in the dust along the street of Kathmandu has been studied by Bhattarai and Shrestha (1981) and came out with a conclusion that there was a direct co-relation between heavy traffic and lead concentration. The accepted standard of lead content for clean air is 0.6 ppm whereas the road side lead contents exceed the level to a great extent.

ENPHO (1993) also conducted a similar study on the lead content at the various sites in the Valley in 1993. The 24 hours concentration of lead content was found to be ranging from 0.18 microgram per square meter in Maharajgunj to 0.53 microgram per square meter in Royal Palace area. That study concluded that the lead concentration in the air of the Valley was within the limit set by WHO.

Sharma and Upadhyaya (1995) monitored the lead pollution in the atmosphere and in the street dust in the Valley. That was the latest study on the lead pollution conducted in the Valley. That study came out with a conclusion that lead concentrations in the street of Kathmandu were many fold higher than the background value found on the normal soil (<0.01 ppm, garden soil in Thapathali). Streets dust in city center with heavy traffic volume showed higher concentration of lead than those in outskirts. Lead content in the air of the city core traffic corridor was above WHO standards of 0.5 - 1 ug/m3 (Sharma and Upadhayaya, 1995).

Stedman and Ellis (1993), in their summary of findings of " Five Nation Asia Motor Vehicle Sampling Tour", mentioned that Bangkok and Kathmandu were much more like Mexico City in their emissions profile than Seoul and Hongkong. It has been mentioned that the average CO level per vehicle tested in the Kathmandu Valley was the second highest mean CO levels (trailing only Mexico City).

3.2 Sources of Vehicular Emissions

There are four possible sources of atmospheric pollution from the automobile. These are carburetor, fuel tank, crankcase and tailpipe (Crouse and Anglin, 1988). Without emission control, the carburetor and fuel tank can emit fuel vapors, the crankcase can emit blow-by gases and fuel vapor, and the tail pipe can give out engine exhaust gas with pollutants in it. Tailpipe exhaust emits the major share of pollutants, about 99 per cent CO, and similar percentage of NO_2 and SOx. Fuel tank and carburetor emits about 20 per cent HC. Crankcase blow-by contains HC and particulate matter as pollutants (Air Pollution in Bangkok, 1992).

There are three main categories of vehicles -- passenger cars and jeeps powered by four stroke engines, two and three wheelers powered by small two-stoke gasoline engines, and buses and light commercial vehicles powered by four-stroke diesel engines. The sources of emission from the four-stoke gasoline vehicles are crankcase blow-by, evaporative emissions, and exhaust emissions. About two per cent of fuel supplied is lost through crankcase emission (Hass, et al., in Mukerjee, 1988). The blow-by discharge into the atmosphere is rich in unburned hydrocarbons (HCs). Evaporative emissions occur via the fuel tank and the carburetor. Exhaust emissions from the gasoline powered engine consist mainly of carbon monoxide (CO), unburned hydrocarbons (HCs), oxides of nitrogen (NOx) and partial oxidation products of the aldehyde family. In addition, particulate matter (PM) - - in the form of lead compounds and carbonaceous matter -- are also emitted from the exhaust emission (Mukerjee, 1988).

Emissions from two-stoke engines are primarily from the two sources, evaporative emissions and exhaust emissions The mechanism for the formation of different pollutants are similar to that of four-stroke engines, except the high concentration of unburned hydrocarbons. The lead compounds exhausted from two-stroke engine consist of inorganic lead salts as well as lead in the form of Tetraethyl Lead (Mukerjee, 1988). The concentrations of carbon monoxide and unburned hydrocarbon in diesel exhaust are rather low, while nitrogen oxide presents in high concentration. Besides these emissions, it contains smoke particulate, and hydro carbons (Mukerjee, 1988).

The two-stoke engine emits a larger amount of hydrocarbons as compared to the four-stroke engine whereas the emission of CO is slightly higher in the four-stoke engine. Four-stoke engine emits quite a high volume of NOx in compared to the two-stroke engine (Mukerjee, 1988). Diesel engine emits a larger amount of HC on idling. Carbon monoxide and NOx are emitted maximum on full load rated speed. There are different level of pollutants emission in between four stroke gasoline and diesel engines and also in between two and four stroke gasoline engine (ONEB, 1987)

3.3 Transport Alternatives and Pollution

There are various types of alternative form of vehicles developed as a viable substitute for the conventional gasoline powered internal combustion engine vehicle (ICEV). These different transport vehicles run on the different fuels. Some of recently developed such alternative automotive vehicles are Battery Powered Electrical Vehicles, BPEV, and Fuel Cell Powered Electrical Vehicles, FCEV (Anderson and Williams, 1994). There are some other type of vehicles categorized in terms of their fuel use. These are the vehicle operating on the reformulated gasoline, diesel, LPG, CNG, methanol from natural gas, methanol from wood, ethanol from maize, ethanol from wood, and liquid hydrogen (Michaelis, 1995a). Wolff and Frosch (1991) also provided a exhaustive list of energy sources for the alternative fuel vehicles.

The comparative assessment of the operational emission among the alternative fuel cars was carried out by Michaelis (1995a). The LPG and the CNG vehicles emit about similar amount of pollutants. The leaded gasoline, without catalyst, produces about 15-25 g/km of CO, 1-3 g/km VOC, 1.5-3.0 g/km NOx and 0.01-0.1 g/km of PM. The unleaded gasoline with three way catalyst produces 1-2 g/km CO, 0.1-0.2 g/km VOC, and 0.1-0.4 g/km. It does not produce any particulate matters. The emission of the electrical vehicle is dependent on the source of electricity. It produces zero emissions when electricity is produced from the hydro power or nuclear power (Michaelis, 1995).

Wolff and Frosch (1991) mentioned about the increasing pressure on motor vehicle manufacturers to develop vehicles which were powered by energy sources other than gasoline. The reasons behind such motivation as they mentioned were the improving air quality by lowering the emission of carbon monoxide and volatile organic compound, and reducing the emissions of green house gases.

3.4 Life Cycle Cost of Transport Options

Michaelis (1995) estimated the costs of using alternative fuel vehicles. He found that in most circumstances, electric vehicles were more expensive on a life-cycle basis than gasoline cars. Vehicles operating on CNG, LPG and diesel cost less than the electric vehicles. Electric vehicle costs 6.81 to 14.74 cents/km, more than the gasoline vehicles. Whereas the diesel , LPG and CNG vehicles cost 0.35 to 3.64, 0.55 to 1.02 and 0.28 to 0.90 cents/km, less than the gasoline.

Michaelis (1995b) in his another study compared the cost of running alternative fuel vehicles. His findings, in terms of cents per kilometer traveled for the different options, were 0.474 cents/km for gasoline, 0.44 to 0.497 for diesel, 0.429 to 0.446 for LPG and 0.566 to 0.676 cents/km for electric vehicle.

3.5 Emission Reduction Cost

Michaelis (1995) estimated the exhaust emission reduction and its associated costs using alternative fuel vehicles. He found that costs of reducing exhaust emissions from the reformulated gasoline car were 0.4 cents/km for CO, 0.005 cents/km for VOC, 0.1 cents/km for NOx and 15 cents/km for GHG CO_{2}- equivalent. Like-wise he found that 1.15 cents/km for CO, 0.05 cents/km for VOC, 0.35 cents/km for NOx and 35 cents/km for CO_2 from the diesel vehicles. The electric vehicles charged from hydro based power station cost 1.5 cents/km for CO, 0.15 cents/km for VOC, 0.25 cents/km for NOx and 214 cents/km for CO_2 for the reduction of exhaust emissions.

Small and Kazimi (1995) also estimated the cost of emission reduction for the selected vehicles using baseline assumption in the Los Angeles region. They found that the costs of emission reduction from 1977 model aged car, were 1.51 cents/km for VOC, 0.78 cents/km for NOx, 1.58 cents/km for SOx and 2.79 cents/km for PM_{10}. The total cost of VOC, NOx, SOx and PM_{10} reduction for the car was 6.65 cents/km. Like-wise, they found that the costs of VOC, NOx, SOx and PM_{10} reduction from the gasoline car were 0.58, 0.81, 0.10 and 0.11 cents/mile.

3.6 GHG Emission from Transport Sector

At present, the most commonly proposed alternatives to petroleum transportation fuels are electricity, methanol, compressed natural gas (CNG and LPG), hydrogen and hybrid. The coal as the primary energy source for transportation fuels generally would caused a large increase in emissions of GHGs, compared to the use of reformulated gasoline. Reformulated gasoline is the gasoline with the lowest C/H ratio hence, the lowest CO_2 emissions (Wolff and Frosch, 1991). The use of natural gas as a primary energy source would in most cases results in slight-to-moderate reductions in CO_2-equivalent emissions, compared to reformulated gasoline (Deluchi, 1993). Electricity, if generated from the solar, hydro power or nuclear, would emits almost zero emission of GHGs.

Three groups, Deluchi et al., Unnasch et al. , and Ho and Renner examined the impact of using alternative motor vehicle fuels on green house gas emissions (Wolff and Frosch 1991). DeLuchi et al. found the relative GHG effect from the natural gas vehicle 81 with respect to the gasoline vehicle for 100. Unnasch et al. found 74 for the diesel vehicle.

The energy sources can be divided into three categories: those that reduce greenhouse gas emissions by 25 per cent or less, those that will increase greenhouse gas emissions, and those that will completely or nearly eliminate greenhouse gas emissions. Diesel fuel, natural gas, LNG from natural gas, clean gasoline, reformulated gasoline, and electric vehicles charged from new natural gas power plant are the fuels of the first category that reduces greenhouse gas emissions by 25 per cent or less. The fuels that result in an increase in greenhouse gas emissions include electric vehicles charged from coal-fired power plants, methanol from coal, ethanol from bio-mass, but produced and transported using fossil fuel and H2 produced from electricity generated from coal combustion. The fuels that result in significant or complete reduction of greenhouse gas are those which utilize electricity generated from non-fossil fuels, hydrogen generated using non-fossil fuel energy and fuels made from bio-mass using energy from bio-mass (Wolff and Frosch, 1991).

There are in-fact more than 20 GHGs. Greenhouse pollutants include emissions of carbon dioxide (CO_2), methane (CH_4), nitrogen oxide (N_2O) and chloro-fluoro-carbons (CFCs). Some of the conventional pollutants such as non-methane hydrocarbon (NMHC) and NOx -- the precursors of tropospheric ozone (O_3) -- and CO contribute indirectly to greenhouse pollution (Mackenzie and Walsh, 1990 in Faiz, 1993).

Worldwide, the transportation sectors contribution to global warming has been estimated at about 20 per cent of the total antropogenic sources (Lashof and Tirpak, 1990 in Greene, 1993). Scenarios based on trend projection with no new policies indicate that transport CO_2 emissions might increase by 40 to 150 per cent between 1990 and 2025 (Michaelis and Davidson, 1996). GHG emissions from transportation sector in developing countries contribute less than three per cent to the global greenhouse effect, compared to a 9 to 12 per cent contribution form transport sector in OECD countries and Eastern Europe (Faiz, 1993).

The problem of formulating an appropriate policy for greenhouse gas emissions is further complicated by the fact that it is truly a global problem. No single country acting alone can solve the problem; joint action is essential (Greene, 1993). The near-term transportation alternatives --fossil fuels -- based methanol, natural gas, LPG, corn-based ethanol and current technology BPEVs using conventional fossil-fuel electricity generally would not provide large reductions in emissions of GHGs, compared to gasoline and diesel (Deluchi, 1993). However, in the long run, the biggest reductions in emissions of greenhouse gases would come from the use of non-fossil energy sources, such as bio-mass or solar energy, with BPEVs or FCEVs. In general, GHG emissions from the transport sector and its energy supply chain can be reduced by policies and measures aimed at reducing energy intensity through vehicle downsizing, controlling emissions of carbon monoxide, VOCs, NOx, N_2O and methane, switching to alternative energy sources with lower full fuel cycle greenhouse gas emissions, and reducing the use of motorized vehicles through switches to non-motorized transport modes (Michaelis and Davidson, 1996). But worldwide vehicular exhaust emissions are estimated to account for about six to seven per cent of the global greenhouse gas emissions. Consequently, converting even the entire global fleet to lower CO_2 emitting vehicles would have only a minor impact (Wolff and Frosch, 1991).

Chapter 4

Methodology

4.1 Selection of Alternative Transport Options

The transport vehicle used in the public and private sector in the Kathmandu Valley are shown in Fig. 4.1 and are categorized in the following three major blocks:

a) Light Passenger Cars

This block of vehicles comprise private cars owned by individuals, private companies, travel agencies, government and semi-governmental organization, and taxis operating as commercial vehicles. These vehicles are powered either by gasoline or diesel. The vehicles of this block have a potential for shifting to the more cleaner fuel vehicles. However, gasoline and diesel car dominate the entire vehicle fleets of this group. Electric and LPG cars are not likely to enter in the vehicle fleets in the Valley in near future. The comparison is limited between the following types of vehicles in this group.

- Gasoline car,
- Diesel car

b) Three-wheelers

There are ,basically, three types of three-wheeler operating in the Valley at present.

- Indian made Tempos (Gasoline and Diesel),
- Electric Vehicles (Locally converted), and
- LPG Vehicles (Thailand made Tuk-Tuk).

c) Bus, Mini-Bus , Trolley Bus, and Battery Powered Minibus

4.2 Vehicle Survey

4.2.1 Sample Selection

The following relation is used to determine the number of sample for the proportional allocation.

$$n = [\sum_{j=1}^{n} Nj\ (\sigma j)^2] / [N\ (\sigma_{xst})^2 + (1/N) * (\sum_{j=1}^{n} Nj\ (\sigma j)^2)] \qquad \text{(Eq. 4.1)}$$

(Source: Newbold, 1990)

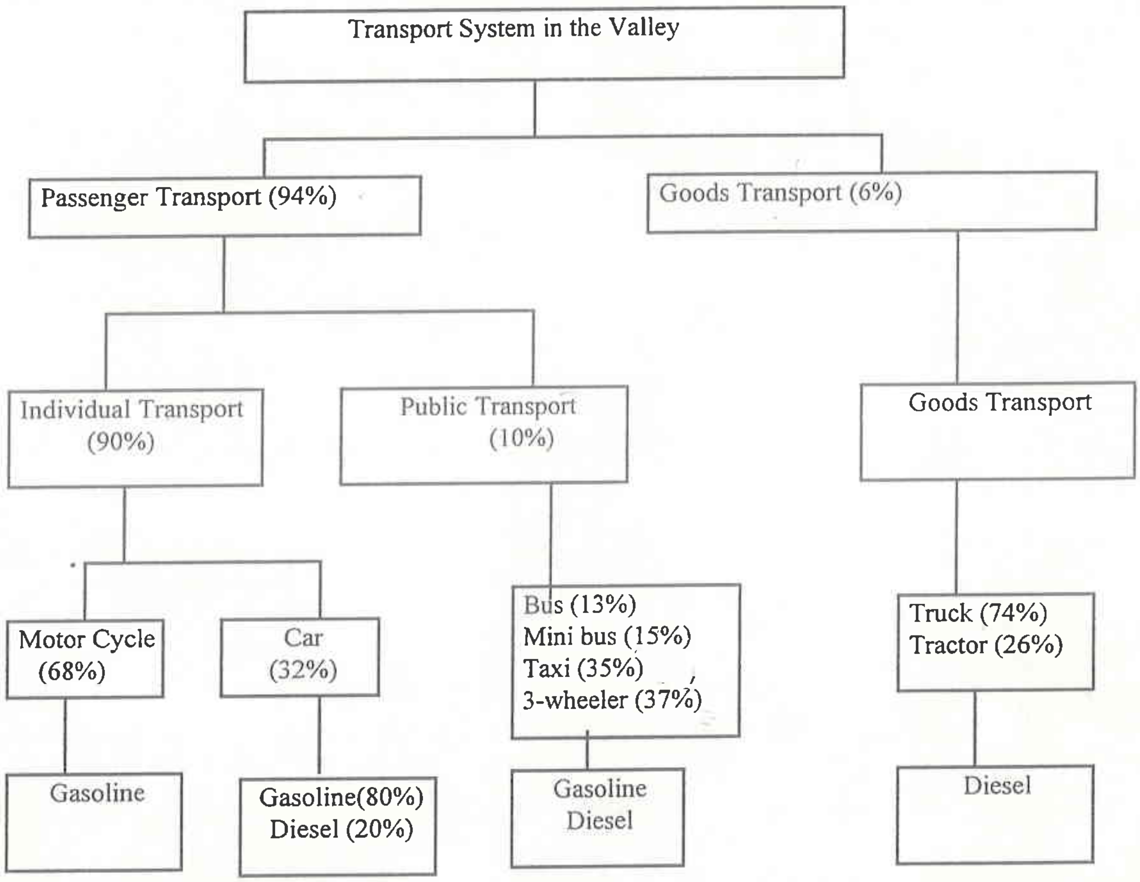

Figure 4.1 Transport System in the Valley

where,

n = Sample size,
N = Total number of vehicles
Nj = Total number of vehicle by type j,
σj = Standard deviation in terms of SFC (Specific Fuel Consumption) of vehicle type i,
σ_{xst} = Standard deviation estimated.

Standard deviation (σj) by vehicle types are taken from WECS (1989) and estimated standard deviation (σ_{xst}) is one with 95% confidence interval.

thus, $1.96\ \sigma_{xst} = 1$
$\sigma_{xst} = 0.51$

The number of sample for the different type of vehicles is calculated by taking their proportional share. The relation for the proportional allocation is;

$n_i = (Ni/N) * n$

where,
n_i = number of sample of vehicle type i.

The number of sample selection is given in the following table.

Table 4.1: Sample Size Allocation

Vehicle Type	Vehicle Population	Estimated SCF (km/l)	Nos. of Sample (Calculated)	Nos. of Sample (Surveyed)
Bus	1283	1.2	4	10
Minibus	1558	1.2	5	10
Car[1]	22505	2.8	61	56
Jeep	5626	3.8	16	16
Tempo	3866	3.5	11	20
Truck	4618	1.2	13	15
2-wheeler	61614	10.8	166	116
Tractor	1674	1.0	4	4
Total	102744[2]		280	247

Information on Trolley bus, Safa tempo and LPG Tuk-Tuk were obtained from their respective organizations.

1 Total number of car/jeep is 28131. It is assumed that there are 80 % cars and 20% jeeps.
2 Total number of vehicle registered in the Valley is 106351. Vehicles registered under UN/CD are excluded here.

A set of questionnaire was prepared to facilitate the field survey work. The field survey questionnaire is attached in Annex 4-1. The breakdown of sample surveyed by ownership type is shown in Table 4.2 given below.

Table 4.2: Number of Sample by Ownership Type

Vehicle	Commercial	Govt./Corporation	Private	Total
Bus	9	1		10
Jeep		7	9	16
Truck	8		7	15
Minibus	10			10
3-wheeler (P)	6			6
3-wheeler (D)	14			14
Taxi	34			34
Car		4	18	22
2-wheeler		4	112	116
Tractor	3		1	4
Total				247

4.2.2 Survey Procedure

Two undergraduate students from the mechanical department of the Engineering College of Nepal (Institute of Engineering, Tribhuvan University, Nepal) were appointed for the survey work. A testing of questionnaire was done before starting the true survey work. The field survey was started on February 10, 1997 and was completed on March 10, 1997. It took about one month to complete the entire survey work. Two stage stratified random sampling technique was adopted for the survey. The first stage involved the selection of check stations on the basis of personal experience, and in the second stage the selection of vehicles was done from the selected check stations by simple random sampling.

Buses, minibuses, and diesel three-wheelers were surveyed on the random basis at the central and old bus terminals. Motorcycles, cars, jeeps, and gasoline powered three-wheelers were surveyed at the gas stations. The survey work for the trucks was carried out at the Kalanki, where most of the trucks park during the off time. Tractors were surveyed in front of National Trading Corporation Building at Teku where the tractors wait for loading the cargoes.

4.2.3 Survey Information Processing

The entire survey information comprise 247 cases and 70 variables. These information were compiled and analyzed using the Statistical Package for Social Science (SPSS).

4.3 Transport Demand Forecast

Transport demand forecast is done by grouping the vehicles in three main categories; public vehicles comprising the bus, minibus, taxi, and three-wheeler, private vehicles comprising car and motorcycle and public goods carrier comprising truck and tractor.

4.3.1 Public Vehicles

Vehicles in this category include the bus, minibus, taxi and three-wheeler operating on the passenger service. The personal transport model developed at the University of Wisconsin in 1985 is taken as the starting point for the vehicle forecast for this category. In this model, trip generation (trips/person/year) is a function of income. Because past data on trip generation is not available with which to develop a model, vehicle ownership is used as a proxy to determine the income elasticity of trip-making. The following methodology is used for the calculation of future trip generation.

i) Calculation of Implied Elasticity of Trip-making

As there is no past data available to estimate the implied elasticity of trip making, vehicle stock of past years is used as a proxy. This is calculated by using the following relation:

$$et = \frac{Ln(Veh)_{t2} - Ln(Veh)_{t1}}{Ln(GDP)_{t2} - Ln(Veh)_{t1}} \qquad \text{(Eq. 4}$$

where,

et = implied elasticity of trip-making
Veh = vehicle Stock
GDP = Gross Domestic Product
t_1, t_2 = past year of data chosen

This elasticity represent also the elasticity of demand for vehicles.

ii) Trips Forecast

Trip generation is related to income. This is given by the following equation:

$$(TRIPS)_{v,t} = (TRIPS)_{v,to} * (GDP_t/GDP_{to})^{et} \qquad \text{(Eq. 4.3)}$$

where,

TRIPS = trips per person per year
v = types of vehicle (bus, minibus, taxi, three-wheeler)
t = future year
to = base year

iii) Calculation of Corrected Implied Elasticity

Using the trip rate of base year and the implied elasticity calculated by using Equation 4.2, number of future trips can be calculated using Equation 4.3. The implied elasticity can be corrected by using the following relation:

$$et' = \frac{Ln(TRIPS)t - Ln(TRIPS)to}{Ln(GDP)t - Ln(GDP)to} \quad \text{(Eq. 4.4)}$$

where,

(TRIPS)t = TRIPS at year t
(TRIPS)to = TRIPS at base year
(GDP)t = GDP at year t
(GDP)to = GDP at base year

iv) Calculation of Vehicle Stock

The corrected implied elasticity thus obtained from Equation 4.4 is further translated to calculate the vehicle stock. The relation to calculate vehicle stock is given below.

$$et' = \frac{Ln(Veh)t2 - Ln(Veh)t1}{Ln(GDPt2 - Ln(GDP)t1} \quad \text{(Eq. 4.5)}$$

This can also be expressed as:

$$(Veh)_{t2} = e^{[[et' * [Ln (GDP)t2 - Ln (GDP)t1]] + Ln (Veh)t1]} \quad \text{(Eq. 4.6)}$$

v) Calculation of Trips for the Base Year

Number of trips for the base year is obtained from the information obtained from the vehicle survey. The number of trips per person per year is calculated by using the following relation.

$$(TRIPS)to = \frac{VehicleNumber * km / year * L.F}{Population * km / trips} \quad \text{(Eq.4.7)}$$

where,

L.F. = Load Factor

4.3.2 Private Car

The schematic flow-chart of the transport demand for car is shown in Fig 4.2.

i) Car Ownership from Income Elasticity

The calculation of the stock of cars is made through the car ownership derived from the household income using an income elasticity. Car ownership is calculated as,

$$(\text{Veh/Population})_t = (\text{Veh/Population})_{to} * (I)^e \qquad \text{(Eq. 4.8)}$$

where,

I = Index reflecting change in the per capita income (=1 for the base year),

$$= \frac{(GDP\ /\ Population)t}{(GDP\ /\ Population)to}$$

e = Elasticity of the car ownership ratio to the per capita income.

The elasticity of the car ownership ratio to the per capita income will be determine from the ratio of growth rate of car ownership ratio and the growth rate of per capita income (i.e. GDP).

ii) Stock of Cars

Stock of car is obtained as

$$Nct = \frac{(Population)t}{(Population\ /\ Veh)t} \qquad \text{(Eq. 4.9)}$$

where,

Nct = Number of car at year t.

4.3.3 Private Motorcycle

The schematic flow-chart for the transport demand forecast for the motorcycle is shown in Fig 4.3.

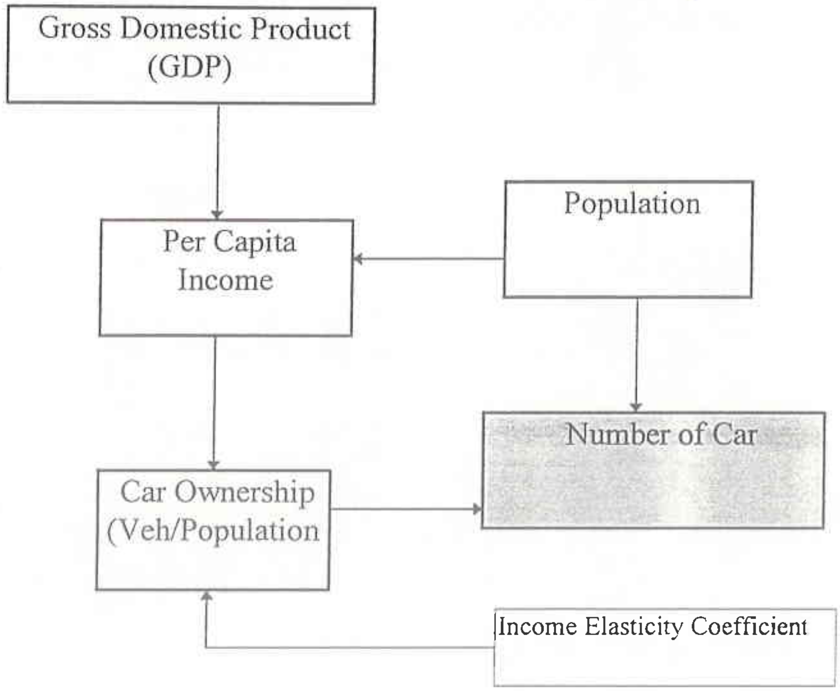

Figure 4.2 Transport Demand of Passenger Car

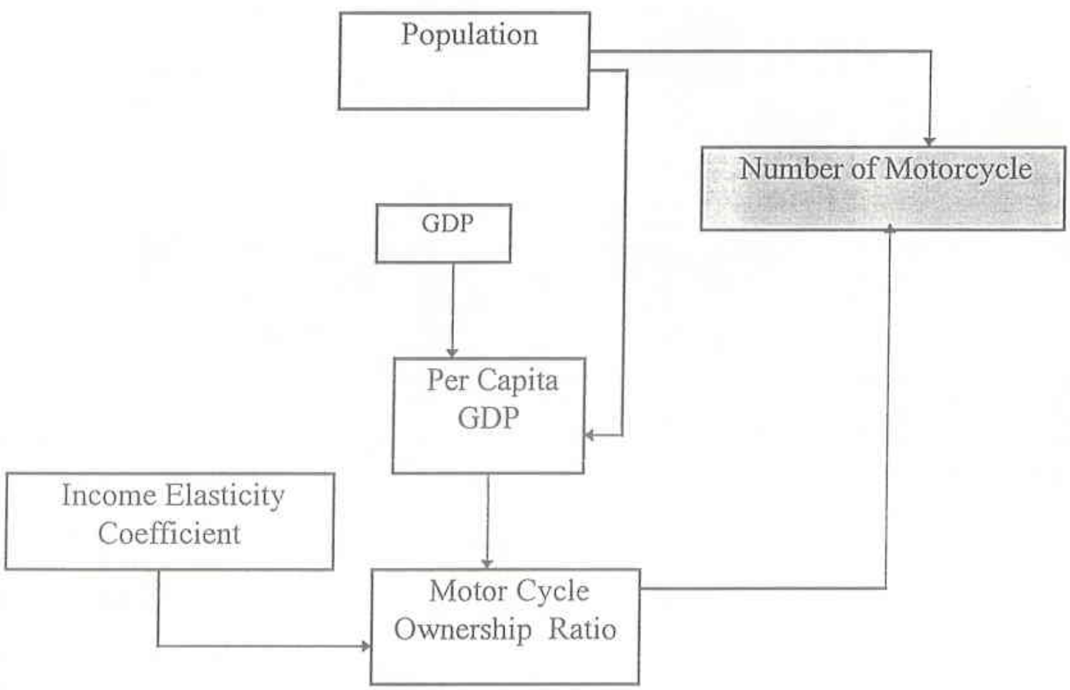

Figure 4.3 Transport Demand of Motorcycle

i) Motorcycle Ownership Ratio

The motorcycle ownership ratio is calculate as,

$$(\text{Veh/Population})_t = (\text{Veh/Population})_{to} * (I)^{e} \qquad \text{(Eq. 4.10)}$$

where,

I = Index reflecting change in GDP per capita

e = Elasticity of motorcycle ownership to per capita GDP

The elasticity of the motorcycle ownership ratio to the per capita income is determined from the ratio of growth rate of motorcycle ownership ratio and the growth rate of per capita income (i.e. GDP).

ii) Stock of Motorcycle

The stock of motorcycle in the year t is calculated as,

$$Nmt = \frac{(Population)t}{(Population\,/\,Veh)t} \qquad \text{(Eq. 4.11)}$$

4.3.4 Tourist, Government and Corporation Vehicles

Tourist, government and corporation vehicle have small share on the total vehicle population. There is no distinct factors that determine their demand. Thus simple growth rate is used to determine future stock.

4.3.5 Truck and Tractor

The forecasting for the future number of trucks and tractor is done by using the simple growth rate model.

4.4 Emissions and Life-Cycle Cost Calculation

The conceptual framework for the life-cycle cost calculation and emission estimation are shown in Fig. 4.4.

4.4.1 Emission Estimation

The vehicle-kilometer (vkm) traveled for any vehicle type is dependent on the total fuel consumption, and specific fuel consumption by the vehicle. Specific fuel consumption is further dependent on speed and age of the vehicles. The mathematical model for the vehicle-kilometer traveled in the case of gasoline vehicle can be expressed as:

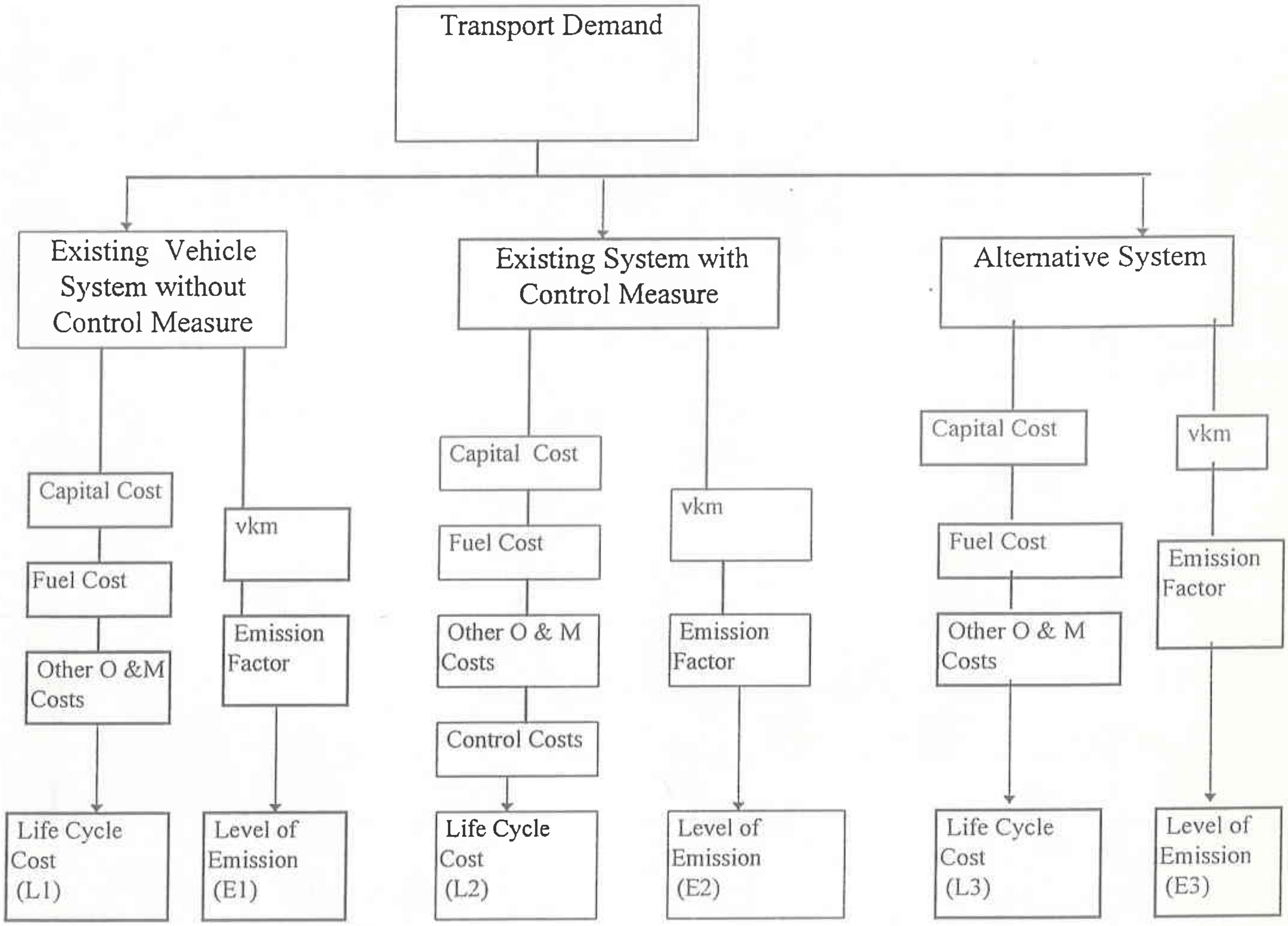

Figure 4.4 Conceptual Framework for the Life Cycle Cost Calculation and Emission Estimation

$$vkm_i = FC_i * SFC_i * s_i * d_i \qquad \text{(Eq. 4.12)}$$

where,

vkm = vehicle kilometer of vehicle type i,

FC = fuel consumption of vehicle type i in liters ,

SFC = specific fuel consumption of vehicle type i in kilometer per liter,

s = speed correction factor [3] for vehicle type i, and

d = deterioration factor for the vehicle type i due to age of the vehicle[4].

The mass emission from vehicle exhaust is calculated from the total number of vehicles in use, the average distance traveled, the fuel consumption by the vehicles and the exhaust emission factors given in gram per kilometer.

Exhaust emission by vehicle type i for pollutant type k in year t is calculated as:

$$EE_{ik}(t) = N_i * vkm_i(t) * Ef_{ik} \qquad \text{(Eq. 4.13)}$$

where,

$EE_{ik}(t)$ = Exhaust emission of pollutant type k by vehicle type i.

N_i = Number of Vehicle type i.

$vkm_i(t)$ = vehicle kilometer traveled by vehicle type i in year t.

Ef_{ik} = Emission factor of pollutant type k of vehicle type i.

4.4.2 Emission Factors

Emission factor is defined as the mass of pollutant emitted per unit of distance traveled. Shrestha and Malla (1996) have estimated the emission factors of vehicles operating in the Valley. These values are used for the calculation of emissions. The emission factors are presented in the following table.

Table 4.3: Emission Factors for Mobile Sources (g/km)

Fuel Type	Vehicle Type	TSPs	CO	HCs	NOx	SO_2	Pb
High Speed Diesel	Truck	3.00	12.00	3.70	13.00	1.75	-
	Bus	3.00	12.00	3.70	13.00	1.75	-
	Minibus	1.50	2.25	1.26	13.00	0.39	-
	Jeep	0.90	3.10	1.30	1.40	0.38	-
	Tractor	0.90	2.25	1.26	1.40	0.39	-
	3-wheeler	1.50	2.25	1.26	13.00	0.39	-

3 Speed correction factor is defined as the ratio of the pollutant-exhaust- emission rate at any speed to the pollutant-exhaust-emission rate at a specified speed.

4 Age correction factor is defined as the ratio of pollutant-exhaust-emission rate at any vehicle-use status in kilometer to the pollutant-exhaust-emission rate at a specified speed kilometer.

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Fuel Type	Vehicle Type	TSPs	CO	HCs	NOx	SO_2	Pb
Gasoline	Car	0.20	~~0.20~~ 62	~~62.00~~ 8.3	~~8.30~~ 2.7	~~2.70~~ 0.13	0.02
	3-wheeler	0.21	~~0.21~~ 22.6	~~22.64~~ 14.13	~~14.13~~ 0.2	~~0.20~~ 0.05	0.02
	2-wheeler	0.50	~~0.50~~ 24	~~24.00~~ 19	~~19.00~~ 0.07	~~0.07~~ 0.02	0.003

Source: Shrestha and Malla, 1996.

Emission factors for the LPG vehicle are taken from the Martin and Michaelis (1992) study. They have estimated the LPG car emission factors of CO, HC, and NOx; which are 18%, 31.5%, and 18.5% of that of the gasoline cars while SO_2 and lead emissions from the tailpipe is eliminated completely. TSP emission factor is assumed to be 25 per cent of gasoline vehicles (Pradhan, 1994).

4.4.3 Life Cycle Cost Calculation

The life cycle operating costs are derived in terms of cents per kilometer. Its calculation requires the following information.

- capital cost components,
- fuel cost,
- other variable costs,
- other costs, such as taxes, insurance etc.,
- average mileage per year,
- life of the vehicle, and
- discount rate.

The concept of levelised cost is adopted as a standard for the comparison of cash flows which occur at different points in time. Levelization involves calculating a stream of equal cash flows whose net present value is equal so that of a given stream of variable cash flows.

The method of calculating life cycle cost involves the following steps.

Step 1

Calculate the net present value (NPV) over the period from the first year of operation of the investment to the end of the life time (n, say).

Step 2

Transfer the NPV to an annuity of equal payments for the period covering the first year of operation to the last year in the life period to give the levelized cost, LC.

$$LC = NPV \quad \frac{i}{1-(1+i)^{-n}} \qquad \text{(Eq. 4.14)}$$

where i = discount rate

Step 3

The life cycle cost (LCC) is obtained by using the following relation:

$$LCC = \frac{LC}{Annuaalkmteaveled} \qquad \text{(Eq. 4.15)}$$

where, the annual mileage for the each vehicle type is found out by the survey.

4.5 Calculation of Pollution Reduction Cost

The cost of emission reduction is determined in the following steps.

Step 1

The life cycle cost is determined in dollar per unit of km basis. Gasoline vehicle is considered as a reference vehicle for calculating the cost of pollution reduction.

Step 2

Emissions are calculated in terms of respective pollutant. Emissions in terms of kilometer traveled are calculated for the all vehicle types.

Step 3

Cost of pollution reduction (CPR) is calculated from the following relation.[5]

$$CPR = \frac{(\text{Life Cycle Cost})_i - (\text{Life Cycle Cost})_{ref}}{(\text{Life Cycle}^{6}\ \text{Emission}_k)_{,ref} - (\text{Life Cycle Emission}_k)_i} \qquad \text{(Eq. 4.16)}$$

where,

---

5 This relation is adopted from Anderson and Williams ,GEF working paper no 6 titled 'The Cost-Effectiveness of GEF Projects'.

6 Life cycle emissions include the emissions on operation only for the purposes of this study. Emissions on extraction, transportation etc. are not considered here.

CPR	= Cost of Pollution reduction ($/ton)
$(\text{Life Cycle Cost})_i$	= Life cycle cost of vehicle type i.
$(\text{Life Cycle Cost})_{ref}$	= Life cycle cost of reference vehicle
$(\text{Life Cycle Emission}_k)_{,ref}$	= Life Cycle Emission (g-k/km) of pollutant for the reference vehicle.
$(\text{Life Cycle Emission}_k)_i$	= Life Cycle Emission (g-k/km) for the pollutant of the vehicle type i.

(where k is the type of emission)

4.6 Impacts on Urban Air Quality[7]

To relate air quality to emissions, the primary tool used was " linear rollback". This is a very simple formula based on the assumption that the concentration of pollutants is proportional to the emissions of pollutants. "Rollback" is a reference to the original application of this assumption, in estimating the percentage reductions of emissions required to roll back concentrations of air pollution to levels prevailing in some former year, levels deemed acceptable and desirable.

The standard rollback formula is,

$$R = \frac{(PAQ)-(DAQ)}{(PAQ)-(B)} \qquad \text{(Eq.4.17)}$$

where,

R = fractional reduction in emissions
PAQ = present air quality (highest concentration recorded)
DAQ = desired air quality
B = background concentration of pollutants (concentration unavoidably present due to natural causes)

Since the purpose here is to estimate future air quality (DAQ) given the current air quality (PAQ), the background level (B), and the fractional reduction in emissions (R), it is necessary to solve the above Equation 4.17 for DAQ:

$$DAQ = PAQ(1-R) + (R) * (B) \qquad \text{(Eq.4.18)}$$

R is estimated from,

$$R = 1 - \frac{Et}{Eb}$$

7 This methodology is extracted and is entirely based on Hamilton (1980).

where,

Et = emissions projected for future and

Eb = emission for the base year.

Information on background concentration are not available for the Kathmandu Valley. Hamilton (1980) calculated the background concentration by analyzing the twenty-four air quality control regions with the largest urban populations in the United States. The background concentrations which are shown below are chosen for analyzing the impacts on air quality in the Kathmandu Valley.

Table 4.4: Background Concentration

Pollutants	Background Concentration
Particulate	10 ug/m^3
Sulfur Dioxide	0
Nitrogen Oxides	10 ug/m^3
Total Hydrocarbons	1 mg/m^3
Photochemical Oxidants	20 - 100 ug/m^3
Carbon Monoxide	1 mg/m^3

Source: Hamilton (1980)

Chapter 5

Transport Demand and Forecasting

5.1 Background

The transportation in Kathmandu Valley is, mainly, done by road transport. The actual development of road transport system in the Valley began in 1960 when two transport companies -- Nav Durga Company and Sajha Yatayat Company -- started their operation. Mass transport has been playing a significant role throughout the history of road transport development, however, individual modes of transport have, recently, started gaining momentum.

Sharp increase in demand for urban transport system has played a significant role in the development of small and medium sized companies to provide transport services in the Valley. At the result , a large number of private companies have been registered and established to operate taxi, bus, minibus, and tempo services in the Valley. Transportation of goods is being mainly done by small-sized trucks and tractors. Heavy trucks are restricted to enter the city center during the day time. Hand carts and power tillers are also being extensively used for the transportation of cargoes in short distances..

An attempt has been made in this chapter to analyze vehicle characteristics and the transport system in order to forecast for the number of future vehicles in the Valley.

5.2 Vehicles Stock

The total number of vehicles registered, as of January 1997, is 106,351. This represents a motorized ratio of 77.5 vehicles per thousand population. The number of vehicles registered in Bagmati Zone as of January 1997 is shown in Table 5.1 given below.

Table 5.1: Number of Vehicles Registered in Bagmati Zone

Type	Tourist	Government	Corporation	Private	Hire	CD/UN	Total
Bus	133	73	45	251	781		1,283
Minibus	96	58	18	378	1,008		1,558
Truck	46	687	280	1,230	2,375		4,618
Tractor		47	18	448	1,161		1,674
Car/Jeep	217	4,485	1,342	18,508	3,579		2,8131
3-W		138	35	255	3,438		3,866
2-W		2,994	1,225	57,395			61,614
CD/UN						3,607	3,607
Total	492	8,482	2,963	78,465	12,342	3,607	106,351

Source: BZTMO (1997)

5.3 Vehicle Characteristics

5.3.1 Vehicle Age

An attempt has been made to find out the average age of the vehicles running in the Valley. Mostly aged buses, minibuses and tractors are seen to be running in the busy street of the Valley. Passenger cars and motorcycles are relatively lesser aged than other vehicles. There are very difficult to see new tractors running in the Valley. The average age of the vehicles running in the Valley is shown in Table 5.2.

Table 5.2: Vehicle Age in Kathmandu Valley

Vehicle Type	Vehicle Age (Year)		
	Minimum	Maximum	Weighted Average
Bus	1	20	9
Jeep	1	5	2
Truck	2	15	5
Minibus	2	22	11
Bajaj 3-wheeler	2	14	8
Taxi	1	26	6
Car	1	10	4
Motorcycle	0.5	10	3
Tractor	12	15	14
Vikram 3-wheeler	5	10	8

Source: Field Survey by author (1997)

5.3.2 Scrapping Rate

The number of vehicles which are running in the Valley can not be known precisely from the vehicle registration data. One of the study conducted by Economic Service Center (1991) came out with the vehicle scrapping rate for Nepal. The Valley is the home for most of the vehicles registered in Nepal, and the scrapping rates estimated for Nepal are , hence, used for Kathmandu. Table 5.3 shows the scrapping rate of vehicles for Nepal.

Table 5.3: Annual Scrapping Rate of Vehicles in Nepal

S.N.	Vehicles	Rate of Scrapping %
1	Bus	4.25
2	Minibus	4.25
3	Truck	2.0
4	Car/Jeep	4.25
5	2-wheeler	5.5
6	3-wheeler	4.5
7	Tractor	4.75

Source: ESC (1991)

The scrapping rates mentioned above for the bus, minibus, car/jeep. 3-wheeler and tractor seem to be within the practical range. It seems to be a bit high for 2-wheeler and a bit low for trucks. These scrapping rates are taken as a reference value and logical adjustment are made while using these figures.

5.3.3 Load Factor

There is a significant deviation from the designed load factor and actual load being carried out by the vehicles in the Valley. The average designed load factor for the bus is found to be 45 passengers per trip but on an average 49 passengers are carried by the buses. Similarly, the average designed capacity of minibus is 30 passengers per trip, but in actual practice 37 passengers are being transported by the minibus. The vehicles operating on the passenger services seem to be over-loaded visibly in busy traffic hours. No vehicles move unless these are completely occupied. Standing capacity is increased in almost all minibuses to accommodate a large number of commuters.

Table 5.4 shows the designed and actual load factor for the vehicles operating in the Kathmandu Valley.

Table 5.4: Load Factor of Vehicles

Vehicle Type	Designed Passenger Capacity	Actual Passenger Per Trip
Bus	45	49
Minibus	30	37
Taxi	4	2.5
3-wheeler (Vikram	9	11
3-wheeler (Others)	3	2.2

Source: Field Survey by author(1997)

5.3.4 Distance Covered Per Day

The average distance covered by the different types of vehicles in the valley varies among the vehicle to vehicle. Minibus covers the maximum distance in a day compared to other vehicles. It covers on an average 155 km in a day. Likewise, bus covers about 137 km per day in the Valley. Table 5.5 shows the distance covered by different vehicles in the Valley

Table 5.5: Distance Covered per Day by Different Vehicles

Vehicle Type	Distance in Km		
	Minimum	Maximum	Weighted Average
Jeep	10	50	27.5
Truck	5	80	18
3-wheeler (P)	30	60	43
Taxi	12	130	77

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Vehicle Type	Distance in Km		
	Minimum	Maximum	Weighted Average
Car	4	35	19
Motorcycle	5	70	18.5
tractor	25	35	28.7
Bus			137
Minibus			155
3-wheeler (D)			97

Source: Field Survey by author (1997)

5.3.5 Running Duration of Vehicles

The operating duration's in a day and a month vary significantly among the different vehicle types. Bus operates 10 hours on an average in a day whereas minibus and 3-wheelers (D) operate for seven hours and 10 hours per day respectively. The operation hour of private car is about 1.2 hours on an average per day. Motorcycle runs about less than one hours per day. Similarly, on an average vehicles run between 22 to 27 days in a month. The running duration of vehicles in the Valley is shown in Table 5.6.

Table 5.6: Running Duration of Vehicles

Vehicle Type	Running Hours in Day			Running Days in Month		
	Min.	Max.	Av.	Min.	Max.	Av.
Bus	7	12	10	25	28	27
Jeep	1	5	1.5	20	30	26
Truck	1	8	4	10	30	22
Minibus	4	10	7	25	30	27.5
Bajaj 3-wheeler	5	10	7.5	25	28	26.5
Taxi	3	12	7	25	30	27.3
Car	0.5	2.5	1.2	15	27	23.3
Motorcycle	0.5	2	0.92	20	30	27
Tractor	4	6	5	25	26	25.5
Vikram 3-wheeler	7	12	10	25	28	26.5

Source: Field Survey by author (1997)

5.3.6 Vehicle By Fuel Type

Majority of vehicles are being run either by gasoline or diesel fuel. About 73 per cent vehicles were found to be running on gasoline fuel. Only 26 per cent vehicles operate on diesel oil in the Valley. Upadhyaya (1996) also mentioned that 75 per cent vehicles were operating on gasoline in the Valley. Bus, minibus, 3-wheeler (D), and tractor use diesel fuel whereas motorcycle, and 3-wheeler (P) are being operated by gasoline fuel. Car, Taxi, and

Jeep run either from gasoline fuel or diesel fuel. But only few cars, jeeps and taxis are being operated by diesel fuel. Table 5.7 shows the vehicle by fuel type in the Valley.

Table 5.7: Vehicle by Fuel Type

Vehicle Type	Sample Surveyed	Fuel Type		
		Gasoline	Unleaded Gasoline	Diesel
Bus	10	0	0	10
Jeep	16	11	0	5
Truck	15	0	0	15
Minibus	10	0	0	10
Bajaj 3-wheeler	6	6	0	0
Taxi	35	32	0	3
Car	21	17	0	4
Motorcycle	116	116	0	0
Tractor	4	0	0	4
Vikram 3-wheeler	14	0	0	14
Total	247	182	0	65
%	100	73.7	0	26.3

Source: Field Survey by author (1997)

5.4 Vehicle Evolution in the Valley

The Kathmandu Valley had few vehicles till 1973. There were all together 1952 buses, minibuses and trucks registered up to that period. The number of cars and jeeps were all together 6012 in 1973. The number of vehicles doubled almost in the period of 1973-1980. Growth trend of vehicles in the Kathmandu Valley are shown in Figure 5.1. There are more or less consistent growth of the number of motorcycles, cars and buses during the period of 1989-1996. Minibuses were increased at a very slow rate. There was abrupt increase in the number of taxis during 1994-1995 and like-wise 3-wheelers increased abruptly during 1990-1991.

Table 5.8 (given in the following page) shows the evolution of transport sector in the Kathmandu Valley since the period of 1989.

5.5 Vehicle Forecast for the Valley

Proper forecasting of vehicle will be instrumental for long term planning prospective in transport sector. Lacking of proper governing policies and inconsistent past development trends make the forecasting task much more completed. difficult, and challenging. There are chances of emerging unknown driving parameters which may change the overall development processes and patterns in the developing countries. However, vehicle forecast based on the present economic scenario and development trends provide ample guidelines and indication for the likely future development in the vehicle fleets.

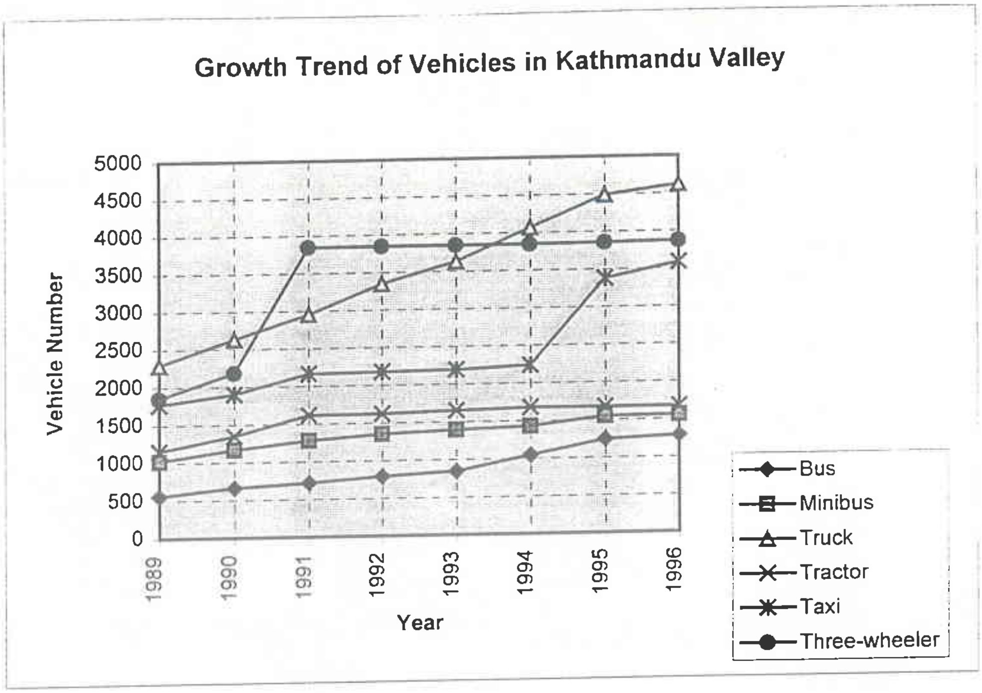
Growth Trend of Vehicles in Kathmandu Valley
Vehicle Number
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
1989
1990
1991
1992
1993
1994
1995
1996
Year
Bus
Minibus
Truck
Tractor
Taxi
Three-wheeler

Figure 5.1

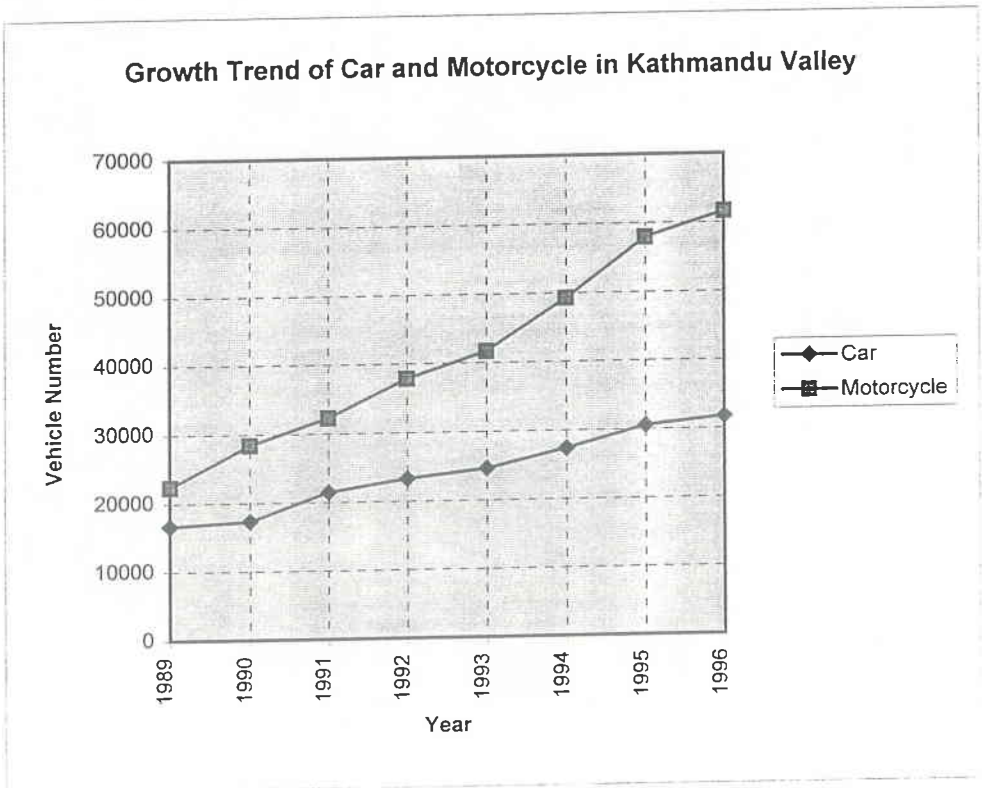
Growth Trend of Car and Motorcycle in Kathmandu Valley
Vehicle Number
70000
60000
50000
40000
30000
20000
10000
0
1989
1990
1991
1992
1993
1994
1995
1996
Year
Car
Motorcycle

Table 5.8:Ownership-wise Vehicles Population in Kathmandu Valley

Vehicle Type	Ownership	Year							
		1996	1995	1994	1993	1992	1991	1990	1989
Bus	Tourist	133	130	36	6	5			
	Government	73	72	69	30	30	28	26	25
	Corporation	45	35	34	34	34	33	32	32
	Private	251	249	238	214	209	204	200	148
	Commercial	781	756	668	563	514	453	405	355
Minibus	Tourist	96	96	19	4	3			
	Government	58	55	54	53	53	45	41	34
	Corporation	18	18	16	13	13	11	11	11
	Private	378	377	364	353	341	329	295	254
	Commercial	1008	1003	975	970	942	892	821	725
Truck	Tourist	46	46	10	3	2			
	Government	687	681	635	603	597	586	570	560
	Corporation	280	275	246	209	202	193	181	172
	Private	1230	1171	1084	1037	958	851	730	574
	Commercial	2375	2315	2089	1773	1584	1320	1150	986
Tractor	Tourist								
	Government	47	47	47	47	46	45	43	41
	Corporation	18	18	18	46	18	18	12	3
	Private	448	448	451	406	405	398	369	337
	Commercial	1161	1161	1161	1154	1154	1154	925	775
Car/Jeep	Tourist	217	215	26	22	22			
	Government	4485	4409	4217	3856	3749	3588	3325	3240
	Corporation	1342	1307	1121	1003	937	867	812	755
	Private	18508	17801	16753	14706	13863	12625	11258	10862
	Commercial	3579	3374	2237	2190	2177	2164	1905	1769
	CD/UN	3607	3410	3007	2806	2561	2215		
3-Wheeler	Tourist								
	Government	138	138	138	138	138	138	137	137
	Corporation	35	35	35	35	35	35	34	33
	Private	255	254	254	254	254	254	215	199
	Commercial	3438	3425	3417	3417	3417	3417	1800	1485
2-wheeler	Tourist								
	Government	2994	2960	2780	2622	2487	2290	2205	2126
	Corporation	1235	1208	1093	1004	959	861	802	788
	Private	57365	53771	45392	38037	34328	29089	25400	19445
	Commercial								

Source:- BZTMO (1997)

5.5.1 Data Sources and Quality

Population

Past data on population is obtained from the past national census. There are some reliable population projection for the Valley. The Central Bureau of Statistics has also published a report on population projection for Nepal. One of the most reliable and recent study on population characteristics of the Valley is completed by National Planning Commission in a collaboration with IUCN (Shah, 1995). This study uses the result of population forecast given in that report. The past and projection of population for the Kathmandu Valley is given in Annex 5.1.

Gross Domestic Product (GDP)

National Planning Commission of Nepal revised the GDP series from 1984 to 1994 for the country in 1994. This is the most recent study done by the governmen. The breakdown of GDP is given on sectoral basis. There are no studies, so far, published that provide the information on GDP for the Valley. One of the study (The Urban Controbution to National Economic Growth, in JICA, 1992) has provided information on the contribution of the Valley to the national economy. It is mentioned that agriculture sector contributes four per cent, mining and quarrying sector 20.6 per cent, manufacturing sector 18.8 per cent and construction sector contributes 28.7 per cent on national economy. Likewise, commercial sector contributes 17.3 per cent, transport and communication sector 27 per cent and financial sector contributes 35 per cent on national economy. This information is used as a starting point for determining GDP for the Kathmandu Valley for the use of this study. Table 5.9 shows the estimation of GDP for the Kathmandu Valley for 1991.

Table 5.9: Estimation of GDP for Kathmandu Valley for 1991 (in million NRs.)

Description	National GDP (1984/85=100)	Contribution of Valley (%)	GDP of Valley (1985/86=100)
Agriculture, Fisheries & Forestry	28070	4	1122.8
Mining and Quarrying	293	20.6	60.36
Manufacturing	4958	18.8	932.10
Electricity & Water	493		
Construction	5962	28.7	1711.09
Commercial	6658	17.3	1151.83
Transport & Commercial	4256	27	1149.12
Finance & Real Estate	5951	35	2082.85
Community & Social Work	5890		
Total	62531		8210.16
Valley Share on GDP (%)			13.13

Source : 1. CBS (1994)

2. The Urban Contribution to National Economic Growth , in JICA (1992)

Agriculture sector contributes the highest share, about 45 per cent, on the national economy whereas the Valley contributes only four per cent on the agriculture sector. This fact can substantiate the 13.13 per cent contribution of GDP from the Valley to the national economy.. One of the recent ESCAP survey (TRN, 1997a) mentioned Nepal's growth rate of 4.8 per cent during the 1980s and in the first half of the 1990s. It further mentioned that Nepal's economy grew by 2.9 per cent in 1995 and six per cent in 1996. The report said that the national economy was expected to grow by six per cent a year in the period until 2000 if present economic trends remain constant. The GDP growth rate of 6.58 per cent (national average for the period 1985-1994) is taken for projecting the future GDP of the Valley in this study. The projection of GDP for the Kathmandu Valley is given in Annex 5.2.

Vehicle Past Data

Past data on vehicle registration are obtained from the government sources. The validity of these sources are very high. However, it does not provide the information on actual number of operating vehicles.

Vehicle Characteristics

Vehicle characteristics like number trips, load factor, trip distance, specific fuel consumption, distance traveled in a year etc. are obtained from the field survey conducted for the purpose of this study.

5.5.2 Forecast for Public Transport

Public transport includes the bus, minibus, taxi, and 3-wheeler operating on commercial sector. The number of trips per person per year is calculated from the base information available from field survey. The future trip is related with the income and population of the study area. The calculation of trips for the base year is shown in Table 5.10.

Table 5.10: Number of Trips per Person per Year

Vehicles	Number of Vehicle	Operating Vehicles	Load Factor	km/year [1]	km/trip	Population (1996)	Trips Nos.[2] (Base Year)
Bus	1032	264	49	44388	17	1372,000	24.61
Minibus	1386	509	37	48360	20	1372,000	33.21
Taxi	3570	2027	2.5	25225	4.9	1372,000	19
3-wheeler	3693	1200	11	30846	6.4	1372,000	46.3

1 km/year = Daily distance covered * Running days in a month * 12

2 Trip = $$\frac{(vehicle) operating}{Population} * \frac{km/year}{km/trip} * \text{Load Factor}$$

Source: Field Survey by author (1997)

As there is no past data available to estimate the implied elasticity of trip making, vehicle stock is used as a proxy. The implied elasticity of trip making for the different types of public vehicle are shown in Table 5.11 and calculation is shown in Annex 5.3.

Table 5.11: Implied Elasticity of Trip-making

Vehicle	1989-1996
Bus	3.35
Minibus	0.27
Taxi	3.4
3- wheeler	4.1

An attempt has been made to compare the elasticity of the vehicle demand in other Asian countries. The elasticity of bus demand to the national income are found 4.37 in case of Malaysia and 5.2 in Indonesia. The elasticity of taxi demand to national income is found to be 6.35 in case of Malaysia. The details of the calculation for the elasticity of vehicle demand in other Asian countries are shown in Annex 5.19. The values of elasticity obtained for other Asian countries and that of Kathmandu Valley resemble closely in many respects.

There are together 1032 buses in private and commercial sectors in the Valley. Its number is expected to increase 1240 in 2000, 1539 in 2005, 1874 in 2010, 2254 in 2015 and 2674 in 2020. This forecast indicates that the number of bus will be doubled by 2012. There are total 1386 minibuses in private and commercial sectors in the Kathmandu Valley. The number of minibus is expected to increase in a very slow pace. The number of minibus will reach 1509 by 2020. There are 3579 taxis operating in the Valley. It is expected to increase by 4.07 per cent per year. The number of taxi is expected to be doubled by 2012. There will be 9406 taxis required to meet the demand in 2020. Three-wheelers are the very popular and are expected to double by 2009 in the Valley. It is expected to increase at the rate of five per cent per year.

Details of the calculation for the vehicle forecasts of bus, minibus, taxi and 3-wheeler for the period of 1997-2021 are given in Annex 5.4, 5.5, 5.6, and 5.7 respectively.

5.5.3 Forecast of Private Car

The number of future car is related to future population, income level and the elasticity of car ownership ratio to per capita income. The following Table 5.12 shows the calculation for the elasticity of car ownership ratio to per capita income.

Table 5.12: Elasticity of the Car-ownership Ratio to Income per Capita.

Year	Population "000"	Car	GDP "million " NRs.	Car (Private)		Income (GDP)	
				Ownership/1000	G. R.	Per Capita	G.R
1989	1027	10862	7373	10.57		7180	
1990	1065	11744	7767	11.03		7293	
1991	1175	12625	8210	10.75		6987	
1992	1128	13863	8452	12.30		7493	
1993	1184	14706	9107	12.42		7692	
1994	1244	16753	9707	13.50		7804	
1995	1306	17801	10345	13.63		7922	
1996	1372	18508	11026	13.50		8036	
Average (geometrical)					3.55		1.62
Elasticity of car ownership to GDP							2.19

The implied elasticity of car demand is also calculated alternatively from the past data using the following relation:

$$e \quad = \quad \frac{Ln(veh/popu)_t - Ln(veh/popu)_{t0}}{Ln(GDP)_t - Ln(GDP)_{t0}} \qquad \text{(Eq. 5.1)}$$

The value of elasticity, thus, obtained is 1.91 which slightly differs from the value obtained from the previous method. An attempt has been made to calculate the elasticity of car ownership , rather car demand to GDP for other Asian countries. The values of elasticity of car ownership to GDP are found to be 6.88 for Malaysia[3], 3.078 for India, 2.19 for Indonesia and 1.57 for Thailand. The value of elasticity for car demand in Nepal is found to be 3.34. The details of calculation for the elasticity in other Asian countries are shown in Annex 5.19. Looking into the values of these and the values obtained from the above calculation, the second value (i.e. 1.99) is chosen here for forecasting the car demand for the Kathmandu Valley.

There are 18508 private cars registered in Kathmandu Valley up to 1996. Using the elasticity of car ownership to GDP of 1.91, the number of private car is expected to double by 2006. There will be more than 118 thousands private cars registered up to the period of 2021 in the Valley. The forecast of car for the year 1997 to 2021 is shown in Annex 5.8.

A sensitivity analysis by taking the different values of elasticity (± 15%) for car demand to GDP is carried out. The result of the sensitivity analysis and corresponding numbers of vehicles are given in Table 5.13 below.

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3 There are different values for different year in Malaysia; 2 for 1978-1980, 0.8 for 1980-1985, 1.0 for 1985- 1987 and 5.5 for 1980-1987 (REDP, 1989a).

Table 5.13: Number of Private Cars at Different Elasticity Values

Year	Elasticity of Car-ownership relating to GDP		
	1.62	1.91	2.2
1996	18508	18508	18508
2000	24706	25101	25503
2005	35363	36607	37895
2010	50441	53114	55930
2015	71777	76798	82170
2020	101884	110636	120141

It is seen that there will be 1.5 and 8.5 per cent change in the number of private car in year 2000 and 2020 with the values of elasticity ±15 per cent respectively. It can be concluded that in short term the value of elasticity is not that sensitive and does not make a vast difference in total number of private car. But in longer term, number of cars is dependent on the values of the elasticity. Forecasting for the short term can be accurately interpreted in but one needs to be careful while interpreting the result of long term forecasting.

5.5.4 Forecast for Motorcycle

Future number of motorcycle (2-wheeler) is the function of population and per capita income of future population. The following Table 5.14 shows the calculation of elasticity of motorcycle ownership ratio to per capita income.

Table 5.14: Elasticity of Motorcycle-ownership Ratio to Income per Capita.

Year	Population "000"	Motor-cycle	GDP "million" NRs.	Motorcycle		Income (GDP)	
				Ownership/1000	G. R.	Per Capita	G.R
1989	1027	19445	7373	18.94		7180	
1990	1065	24265	7767	22.77		7293	
1991	1175	29089	8210	24.75		6987	
1992	1128	34328	8452	30.48		7493	
1993	1184	38037	9107	32.05		7692	
1994	1244	45392	9707	36.50		7804	
1995	1306	53771	10345	41.15		7922	
1996	1372	57365	11026	41.84		8036	
Average (geometrical)					11		1.62
Elasticity of motorcycle ownership to GDP							6.5

The implied elasticity of motorcycle demand is also calculated alternatively using the same relation as in Equation 5.1. The implied elasticity obtained by calculating this method is

6.7 which is very close to the value obtained above. However, the values thus obtained seem to be very high.

An attempt has also made here to calculate the elasticity of motorcycle ownership, rather motorcycle demand to GDP in other Asian countries. It is found that the value for Malaysia is 7.8[4], India 3.8, Indonesia, 3.55 and Thailand 2.62. Details of this calculation is shown in Annex 5.19. The World Bank calculated the value of elasticity for motorcycle demand for the Philippines in 1981 and came out the finding of elasticity of 1.8 (Galido, 1988). Here, looking into the above facts and values, elasticity of motorcycle demand is taken as 2.0 for forecasting the motorcycle in the Valley.

There are 57365 private motorcycles registered up to 1996 in the Valley. Using the elasticity of motorcycle ownership to GDP as 2.0, it is expected to increase the number of motorcycles to 351788 by 2020 in the Valley. The number of private motorcycle is expected to double from the present level by 2005. The forecast of motorcycle for the year 1997 to 2021 is shown in Annex 5.9.

A sensitivity analysis by taking the different values of elasticity (± 15%) of motorcycle demand to GDP is carried out. The result of the sensitivity analysis and corresponding numbers of vehicles are given in Table 5.15 below.

Table 5.15: Number of Motorcycle at Different Elasticity Values

Year	Elasticity of Motorcycle-ownership relating to GDP		
	1.75	2	2.3
1996	57363	57363	57363
2000	77119	78182	79476
2005	111316	114684	118860
2010	159996	167281	176462
2015	229310	243074	260685
2020	327661	351788	383096

It is seen that there will be 1.3 per cent and 7.2 per cent change in the number of private motorcycle in year 2000 and 2020 with the values of elasticity ±15 per cent respectively. It can be concluded that in short term the value of elasticity is not that sensitive and makes not a vast difference. But for the long term the result obtained thus should be used very carefully.

5.5.5 Forecast other Vehicles

An attempt has been made to find the correlation between growth rate of tourist vehicles and the number of tourist entering the country. But there were no significant relationship between these two factors. There were relatively few tourist vehicles registered

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4 There are different values of elasticity for different year in Malaysia; 1.2 for 1978-80, 2.9 for 1980-1985, 4.1 for 1985-1987, and 5.8 for 1980-1987 (REDP, 1989a).

in the year when tourist flow was more in the country. Similarly, numbers of government and corporation vehicle are found to be increasing not in accordance with the ratio of their respective expenditures for the respective years. The shares of tourist, government, and corporation vehicles are not as high as compared to private and commercial vehicles. Forecasting for these categories of vehicles is, therefore, carried out using simple growth rate model for the respective vehicles. The growth rates of tourist, government and corporation vehicles are shown in Annex 5.10.

Growth rate of the tourist vehicles is very high and which may not provide the actual trend for the future registration. So, for the tourist vehicle projection , growth rate of total vehicle is taken as the reference. Similarly growth rate of government bus is adjusted by omitting the inconsistent growth rate for some exceptional year (i.e. year 1994).

Projections of tourist , government and corporation vehicles are given in Annex 5.11, 5.12, and 5.13 respectively.

Growth rates of truck and tractor are shown in Annex 5.14. Forecasting of private and commercial trucks are done by the average growth rate of vehicles in the Kathmandu Valley. The past trend of truck growth rate is very high and which does not look appropriate for the truck forecasting in the Valley. The number of tractor is forecasted with its growth rate in the Valley. The number of future trucks and tractors of the private and commercial sectors are shown in Annex 5.15.

5.6 Number of Future Vehicles

There are 1283 buses registered in the Kathmandu Valley up to 1996. These will reach to 5656 by the year 2021. The population of the bus is expected to double from the present number by 2009. The number of bus will increase by 6.11 per cent per annum. There are 1558 minibuses registered in the Kathmandu Valley up to the period of 1996. These numbers are not expected to double even by the year 2021. The registration of minibus is expected to increase by only about two per cent per annum. By the year 2021, there will be about two thousands and five hundreds registered minibuses in the Kathmandu Valley.

There are 4620 trucks registered in the Valley till 1996. It is expected to increase by the rate of 5.3 per cent per year. The population of truck will double by 2010. There will be total 16748 trucks registered by 2021 in the Kathmandu Valley. There are 1674 registered tractors in the Valley till 1996. The number of tractor is expected to increase by 5.66 per cent per year. The number of tractors will be double by the year 2009. There will more than six thousands tractors registered in the Valley by 2021.

There are about 28 thousands passenger cars registered in the Kathmandu Valley till 1996. The car registration will increase by 7.09 per cent per year. The number of car will double by the year 2007. There will be more than 156 thousands car by the year 2021 in the Kathmandu Valley. There are about four thousands 3-wheelers registered in the Kathmandu Valley till 1996. This number is expected to increase by 4.79 per cent per year if the present growth rate remains. The number of 3-wheeler will double by 2010 and will reach 12469 by 2021. Similarly, there are more than sixty thousands motorcycles registered till 1996 in the Kathmandu Valley. It is expected to increase by the rate of 7.72 per cent per year. This number will double from the present level by 2006 and is expected to reach nearly four-hundred thousands by 2021. The following Table 5.16 shows the number of vehicles in the Kathmandu Valley.

Table 5.16: Present and Forecasted Number of Vehicles in Kathmandu Valley

Vehicle	1996	2000*	2005*	2010*	2015*	2020*
Bus	1283	1594	2100	2788	3779	5270
Minibus	1558	1634	1751	1904	2107	2385
Truck	4620	5647	7278	9409	12203	15881
Tractor	1674	2065	2724	3595	4748	6273
Car/Jeep	28131	37007	52148	73410	103420	145768
3-wheeler	3866	4761	6160	7805	9747	11983
2-wheeler	61594	83427	121557	176298	254921	367376
Total	102726	136135	193718	275209	390925	554936

* Forecasted

Details of future vehicles are shown in Annex 5.16.

5.7 Number of Future Vehicles with Adjustment

Three-wheeler has become very popular in the Kathmandu Valley since last decade and has, also, a reputation of being highly polluting vehicle. Government imposed ban on further registration of this vehicle in the Valley. It is now necessary to adjust the number of vehicles considering that there will be no more registration for 3-wheelers in the Valley. It is practical to assume that most of the passengers who would be getting the service of 3-wheelers, will shift to minibus. Tariff rates of minibus and 3-wheeler are very close. Three-wheelers are providing almost similar type of service as that is being provided by the minibus.

The equivalent number of minibus for the 3-wheelers is determined by considering the load factor, distance per trip and number of trip of 3-wheeler and minibus in the Valley. One minibus is found to be equivalent of six 3-wheelers[5] and further adjustment of minibus and 3-wheeler is done considering this equivalent number.

[5]

$$\text{One Minibus} = \frac{(\text{load factor})_{minibus}}{(\text{load factor})_{3\text{-}w}} * \frac{(\text{Distance/trip})_{minibus}}{(\text{Distance/trip})_{3\text{-}w}} * \frac{(\text{Number of trips})_{minibus}}{(\text{Number of trips})_{3\text{-}w}}$$

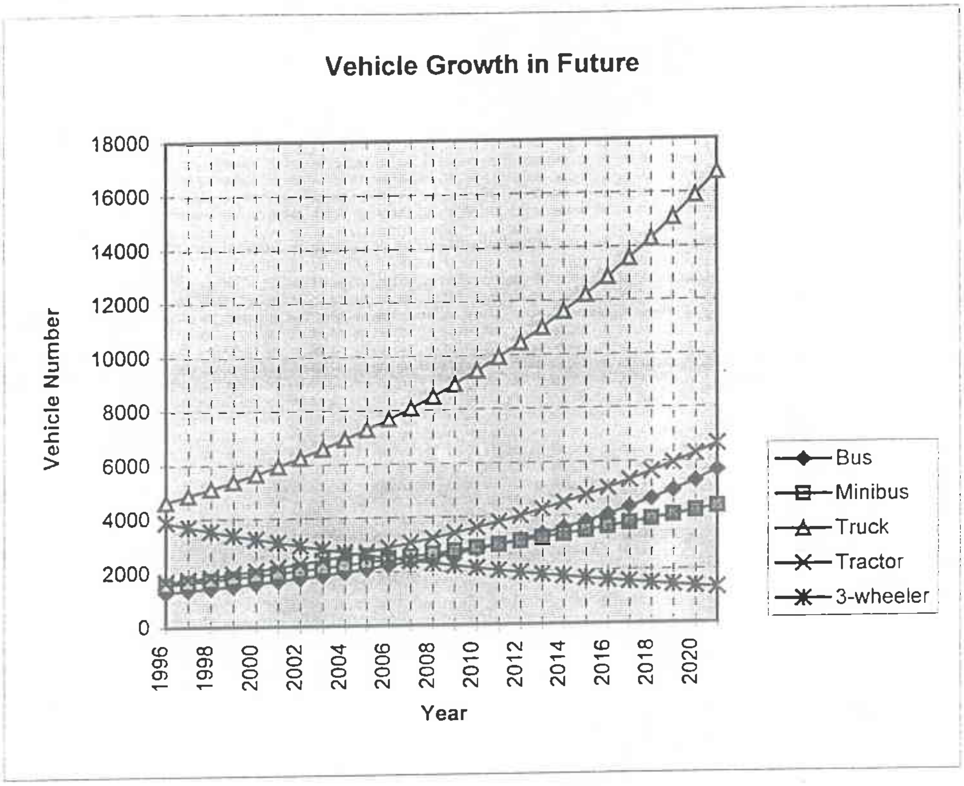
The number of minibus required for the replacement of 3-wheelers are shown in Annex 5.17. The numbers of future vehicles with adjustment for 3-wheelers are shown in Table 5.17. Details of future number of vehicles are shown in Annex 5.18.

Table 5.17: Number of Future Vehicles with Adjustment

Vehicle	2000	2005	2010	2015	2020
Bus	1594	2100	2788	3779	5270
Minibus	1888	2343	2855	3450	4156
Truck	5647	7278	9409	12203	15881
Tractor	2065	2724	3595	4748	6273
Car/Jeep	37007	52148	73410	103420	145768
3-wheeler	3240	2608	2099	1689	1359
2-wheeler	83427	121557	176298	254921	367376
Total	134868	190758	270454	384210	546083

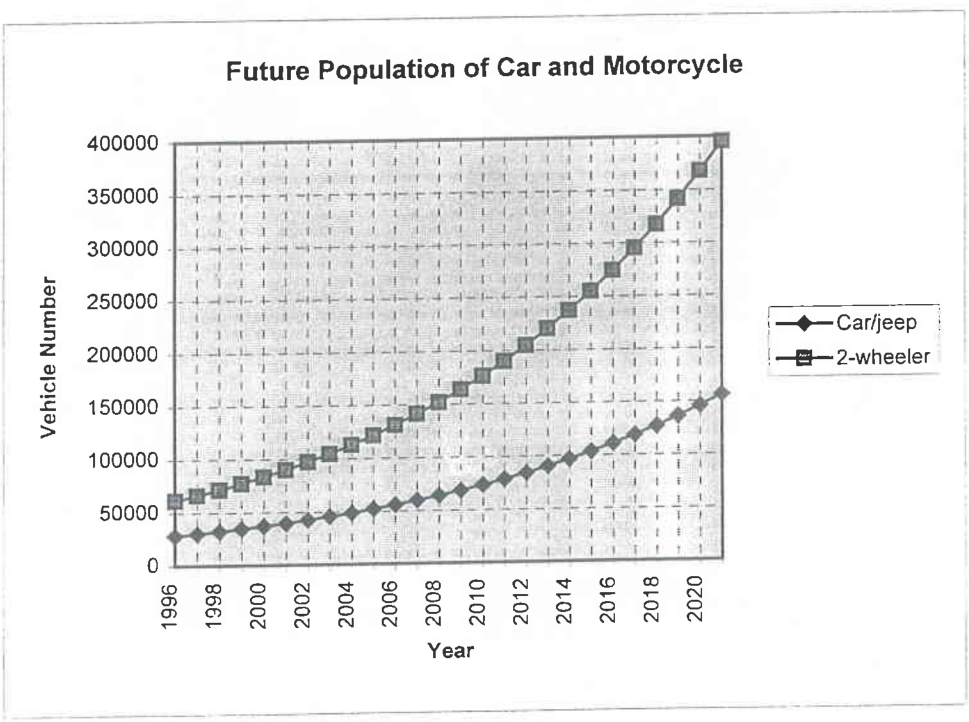
5.8 Conclusion

The trends for the future vehicle growth are shown in Figure 5.2. The vehicles will grow at the rate of 7.3 percent per year in future. Motorcycles will grow at the highest rate, 7.8 per cent per year followed by cars, 7.0 per cent per year. Other vehicles are expected to increase at a bit slower rate as were experienced in the past. There will be no further registration of 3-wheelers using oils and it, hence, goes on decreasing. There will be more than 500 thousands vehicles registered by 2020 in the Valley, of which 2-wheelers comprise about 67 per cent of the total vehicle.



Vehicle Growth in Future
Vehicle Number
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year
Bus
Minibus
Truck
Tractor
3-wheeler

Figure 5.2



Future Population of Car and Motorcycle
Vehicle Number
400000
350000
300000
250000
200000
150000
100000
50000
0
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Year
Car/jeep
2-wheeler

Chapter 6

Vehicular Emissions and Impacts on Air Quality

6.1 Background

This chapter concentrates on the estimation of present and future emissions of pollutants from vehicles in the Kathmandu Valley. Furthermore simple "roll back" method is applied here to analyze impacts of vehicular emissions on air quality of the Valley.

6.2 Vehicle Parameters for Emission Estimation

6.2.1 Specific Fuel Consumption

Specific fuel consumption (SFC) for the vehicles operating in the Valley is determined from the primary survey. The results of the survey on specific fuel consumption is given in Table 6-1.

Table 6.1: Specific Fuel Consumption of Vehicles

Vehicle Type	Specific Fuel Consumption (km/liter)		
	Minimum	Maximum	Weighted Average
Bus	3	5	3.5
Jeep	6	20	13.4
Truck	3	10	5
Minibus	3	5	4.3
3-wheeler (P)	10	20	15
Taxi	8	20	13.6
Car	11	25	15.5
Motorcycle	30	65	45.4
Tractor	3	8	5.7
3-wheeler (D)	6	16	11.2

Source :-Field Survey by the author

The information on SFC of the vehicles in other Asian countries are gathered from the different sources. There is a slight variation in the figures of SFC among the countries. These variations may have arisen due to the variations on the factors mentioned somewhere else in this report. The specific fuel consumption in other Asian countries are shown in Table 6.2.

Table 6.2: Specific Fuel Consumption of Vehicles in Asian Countries (km/Liter)

Vehicle	Philippines	Sri Lanka	Laos	Korea	Thailand	Kathmandu
Bus	2.77		5	4.5	4	3
Jeep						8
Truck			5	5.6		4.5

Continue..

Vehicle	Philippines	Sri Lanka	Laos	Korea	Thailand	Kathmandu
Taxi	9.56		9	9.8	11	10.6
Car	8.3	8.5	9	9.8	11	10.6
Motorcycle	33.33	34.77	33	38	32	45.5

Source: UN (1992c), UN (1992b), UN (1992a), REDP (1989b), REDP (1989e) and Shrestha and Malla (1996).

The specific fuel consumption of buses and trucks are almost in the same range in Kathmandu and other Asian countries. Survey information on SFC for cars, jeeps and taxies differs from the information shown in the Table 6.2. It seems to be overstated the fuel consumption for those vehicles in the Kathmandu Valley. The specific fuel consumption for the cars, taxis and jeeps are, hence, considered 10 km per liter for the purpose of emission estimation here. Specific fuel consumption of motorcycles seems to be higher in Valley compared to other Asian countries but complies with the result of Shrestha and Malla (1996).

6.2.2 Fuel Consumption by Different Vehicles

Daily fuel consumption of vehicle is dependent on fuel efficiency or specific fuel consumption, distance covered by vehicles, types of vehicles, driving speed and other driving parameters. The details of daily, monthly and yearly fuel consumption of the vehicles in the Valley is shown in the following Table 6.3.

Table 6.3: Fuel Consumption by Different Vehicles (liters)

Vehicle Type	Daily			Monthly			Yearly
	Min.	Max.	Average	Min.	Max.	Average	Average
Bus	25	52	38.7	700	1500	1075	12900
Jeep	1	40	5.2	30	150	72.8	874
Truck	1	50	11.3	15	800	264	3168
Minibus	12	65	35.7	324	2000	1053	12636
3-wheeler (P)	4	6	4.8	100	175	117.5	1410
Taxi	1	15	7.6	23	350	206	2472
Car	0.5	3	1.62	20	100	40	480
Motorcycle	0.25	2	0.66	0.75	60	19	228
Tractor	5	20	9.25	100	600	240	2880
3-wheeler (D)	5	15	8.67	150	450	235	2820

Source : Field Survey by the author

6.2.3 Vehicle Speed

Vehicle speed is dependent on the of congestion on the road. The average speed of buses is found to be 39 kilometers per hour whereas average speeds of jeeps, trucks, and minibuses are 53.2, 37.3 and 39 kilometers per hour respectively. Table 6.4 exhibits the speed of different vehicles in the Kathmandu Valley. It is clearly seen that the average speed of most of the vehicles lie within the range of 35 to 50 kilometer per hour in the Valley.

Table 6.4: Vehicle Speed (km/hour)

Vehicle Type	Speed (km/hour)		
	Minimum	Maximum	Average
Bus	30	50	39
Jeep	20	60	53.2
Truck	25	50	37.3
Minibus	30	45	39
3-wheeler (P)	30	40	36.6
Taxi	25	60	47
Car	25	75	45
Motorcycle	25	60	40.8
Tractor	8	12	10.5
3-wheeler (D)	30	50	38.2

Source: Field Survey by the author

There are some other studies (JICA, 1992 and IF, 1997) which have also studied the speed patterns of the vehicles in the Valley. It is mentioned in the JICA report that the vehicle speed is in the range of 20 - 55 kilometer per hour in the Kathmandu road condition. This results are further validated with the findings of the study conducted by IF (1997). It is found that the speed ranges from about 20 kilometer per hour to about 60 kilometer per hour.

6.2.4 Population of Operating Vehicles

Vehicles operating on public transport services such as buses, minibuses, 3-wheelers, taxis need to secure route permit from the zonal transport office. A list of vehicles and their specified routes are shown in Annex 6-1. There are no other reliable sources which provide enough information on the number of other vehicles (except the vehicles mentioned in above) which are actually operating in the Valley. An attempt has been made to estimate the number of operating vehicles with considering the scrapping rate.

It was the 1950s when the Valley started experiencing the road vehicles. There were almost negligible vehicles before that period. It is practical to assume that vehicles started scrapping only after 1980 for the bus, minibus, truck and tractor. Car and motorcycle became popular only after the 1960s. It is assumed that car and motorcycle started scrapping only after 1990. A table showing the lists of operating vehicles is given in Annex 6-2.

6.2.5 Speed and Age Correction Factor

Most of the vehicles operating in the Valley have the speed within the range of 30 -45 km/hour. Speed correction factor is nearly one for the vehicles at the speed range of 30-40 km/hour. Hence, speed correction factor of one is used for the calculation. Similarly age correction factor is taken as one.

6.3 Vehicle Emission in the Valley

Average vehicle kilometer (vkm) is the function of average fuel consumption (refer Table 6.2), specific fuel consumption (refer Table 6.1), speed and age correction factor. Parameters which are required for the emission estimation, are shown in Table 6.5 below.

Table 6.5: Vehicle Parameters for Emission Estimation

Fuel Type	Vehicle Type	AFC (liter)	SFC (km/liter)	Operating Vehicles	Total Vehicle Km (vkm)
Diesel	Truck	3,168	5	720	15,840
	Bus	12,900	3.5	613	45,150
	Minibus	12,636	4.3	745	54,335
	Jeep	874	10	4,373	8,740
	Tractor	2,880	5.7	732	16,416
	3-wheeler	2,820	11.2	1,200	31,584
Gasoline	Car (Taxi)	2,472	10	2,027	24,720
	Car	480	10	15,462	4,800
	3-wheeler	1,410	15	1,800	21,150
	Motorcycle	228	45.4	39174	10,351

Transport sector contributed about 31 thousands tons of pollutants in 1996 from the existing number of vehicles in the Kathmandu Valley. The details of the pollutants emission from the different transport vehicles are shown in Table 6.6. CO was the major pollutants and constituted about 60 per cent on the total emission. There was above 19 thousands tons of CO emitted from the transport sector in the Valley. Other major pollutants were HCs and NOx. Their contributions on the total emissions were 30 per cent and six per cent respectively.

Table 6-.6: Vehicle Emissions in Kathmandu Valley (1996)

Fuel Type	Vehicle	Emission (ton)						
		TSPs	CO	HCs	NOx	SO_2	Pb	Total
Diesel	Truck	34	137	42	148	20		381
	Bus	83	332	102	360	48		926
	Minibus	61	91	51	526	16		745
	Jeep	34	118	50	54	15		271
	Tractor	11	27	15	17	5		75
	3-W	59	88	49	509	15		721
	Total	282	794	310	1614	119		3118

Continue..

Fuel Type	Vehicle	Emission (ton)						
		TSPs	CO	HCs	NOx	SO_2	Pb	Total
Gasoline	Taxi	10	3107	416	135	7	1	3675
	Car	15	4601	616	200	10	1	5444
	3-W	8	890	556	8	2	1	1465
	2-W	203	9732	7704	28	8	1	17677
	Total	236	18330	9292	372	26	4	28260

Emissions from different vehicles are shown in Figure 6.1.

6.3.1 Emission from Diesel Vehicles

Among the total vehicle registered, there were about 20 per cent diesel vehicles in the Valley. It is found from the above analysis that there are 13 per cent vehicles operating on diesel fuel in the Valley. Diesel vehicles contribute about 10 per cent of the total pollutants emission in the Valley. The remaining amount of pollutants are contributed by gasoline vehicles. Share of pollutants from diesel vehicles are shown in Figure 6.2.

6.3.2 Emission from Gasoline Vehicles

Gasoline vehicles constitute about 80 per cent of the total registered and about 87 per cent of the operating vehicles in the Valley. Gasoline vehicles contributed 28260 tons of pollutants which was about 90 per cent of the total vehicular emissions in the Valley in the year 1996. The major pollutants were CO -- about 68 per cent-- and HCs -- about 30 per cent. There were small traces of other pollutants, such as NOx, TSPs, SO_2 and Pb emitted by the gasoline vehicles. Share of pollutants from gasoline vehicle are shown in Figure 6.3.

6.3.3 Local Pollutants

CO and HC constituted 61 per cent and 30 per cent of the total pollutants emission from the transport sector. TSPPs constituted about two per cent of the total pollutants emission from the transport sector in the Kathmandu Valley. Motorcycles were the major contributors of the HCs and, alone, emitted more than 80 per cent. Two-wheelers, cars and taxis were the main source of CO emission. Two-wheelers contributed 39 per cent on the total TSPs emission. Shares of different pollutants from vehicular emission are shown in Figure 6.4.

6.3.4 Sensitivity Analysis

There are variations on the values for the average fuel consumption of vehicles between the finding of the survey done for this study and findings of other reports, such as Shrestha and Malla (1996). These values are a bit sensitive to the various driving conditions

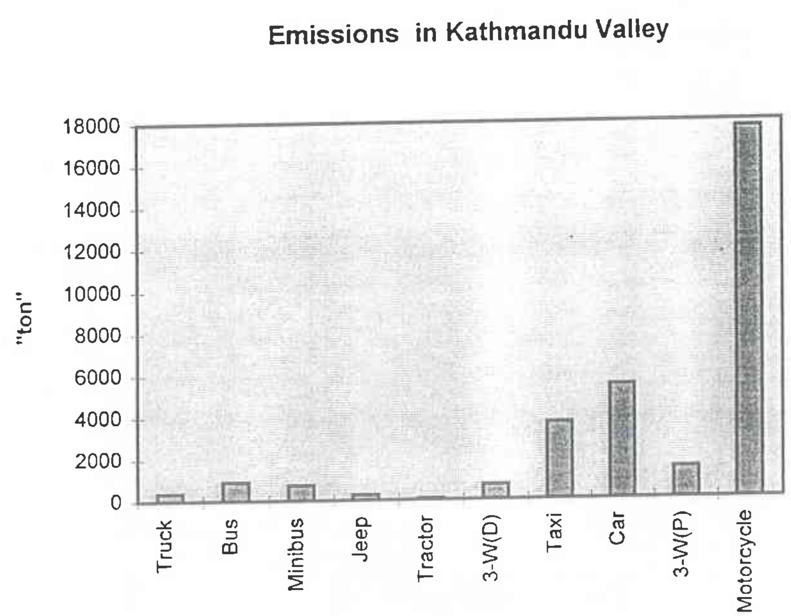


Figure 6.1

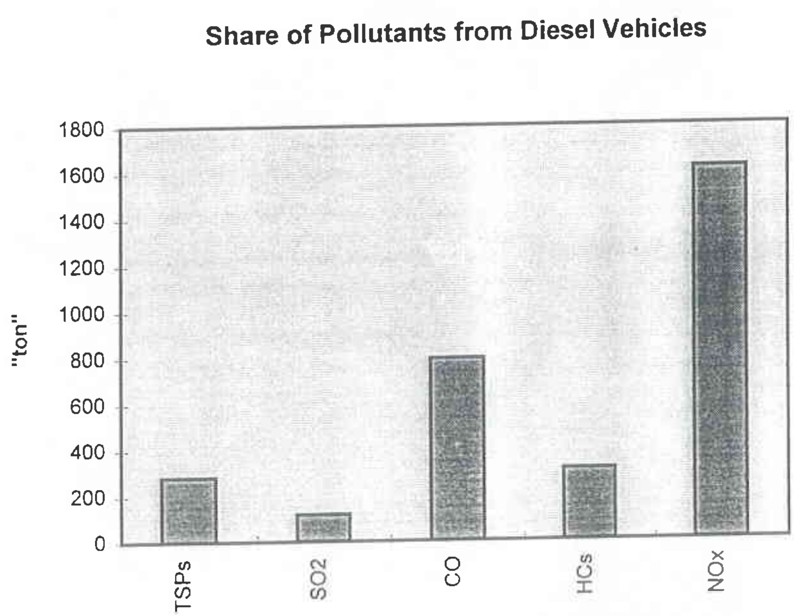


Figure 6.2

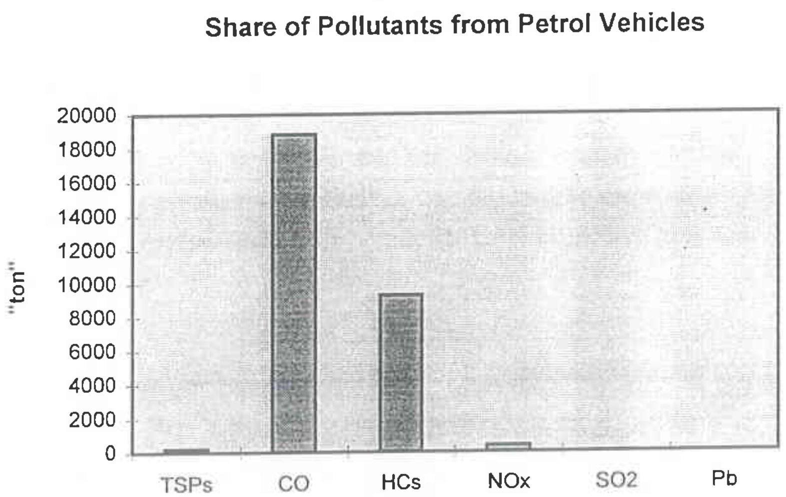


Figure 6.3

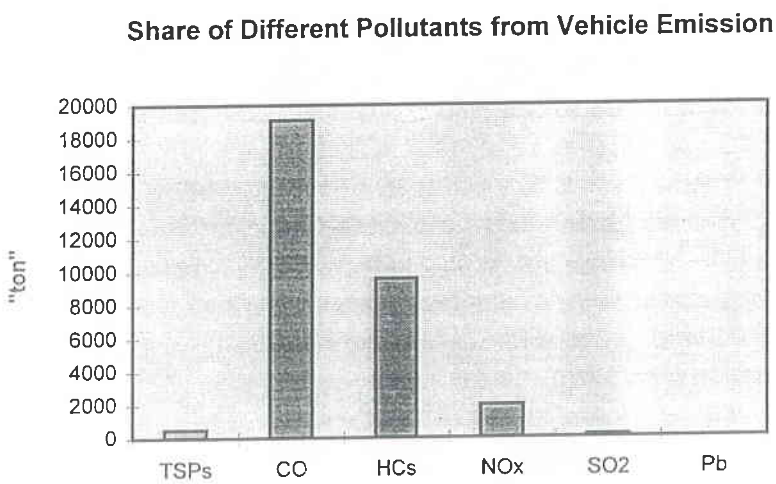


Figure 6.4

and the parameters on which fuel consumption depends. Annual distance covered and the specific fuel consumption are subject to vary in actual practice. A sensitivity analysis is, hence, carried out to see the change in emission level at the different values of vehicle kilometer traveled because it takes into the account of both specific fuel consumption and average fuel consumption. Table 6.7 shows the change in emission level of different pollutants at ±5%, 10% and 15% change in vehicle kilometer.

Table 6.7:- Tons of Pollutants at Different Vehicle Kilometer

Pollutants	Vehicle Kilometer (vkm)			
	-5%	+5%	+10%	+15%
TSPs	492	544	570	617
CO	18168	20080	21036	22331
HCs	9121	10082	10562	11252
NOx	1886	2085	2184	2445
SO_2	138	152	159	172
Pb	4	5	5	5
Total	29809	32947	34516	36822

It can be concluded , from this sensitive analysis, that the Valley experienced the total vehicular emissions in the range of 29 to 36 thousands tons in the year 1996.

6.4 Emission Per Passenger -Kilometer

An attempt has been made to estimate the emission per passenger-kilometer for the public passenger vehicles. Three-wheeler(D) has the greatest emission per passenger-kilometer traveled in the Valley. It emits three times more TSPs per passenger-kilometer compared to minibus and about two times more than that of the bus. The level of CO emission per passenger-kilometer is more in bus compared to minibus and 3-wheeler is the highest among these vehicles Bus emits about 1.25 times more CO than 3-wheeler and about four times more CO than minibus. HC emission is highest in 3-wheeler compare to minibus and bus. It emits about 1.5 times more and 3.4 times more HC per passenger-kilometer than bus and minibus respectively. Likewise, NOx emission per passenger-kilometer of 3-wheeler. But bus has the highest the SO_2 emission per passenger-kilometer compared to minibus and 3-wheeler. Table 6.8 given below shows the emission of pollutants per passenger-kilometer of the diesel public transport vehicles.

Table 6.8 : Emission per Passenger-Kilometer (gm/passenger-kilometer)

Vehicle	TSPs	CO	HCs	NOx	SO2
Bus	0.064	0.258	0.079	0.28	0.03
Minibus	0.0419	0.062	0.034	0.36	0.01
3-wheeler (D)	0.135	0.205	0.1155	1.18	0.024

6.5 Emission from Unit Vehicles

In actual driving conditions, there are different amounts of per unit pollutants emission from the different types of vehicles in the Valley. In an average one unit of taxi emits about 1.8 tons of pollutants in a year. Like-wise a single unit of bus and minibus emit about 1.5 tons and one ton of pollutants in a year respectively. Table 6.9 shows the emission from unit vehicle in the present driving conditions in the Valley.

Table 6.9: Emission from Unit Vehicle

Fuel Type	Vehicle	Emission (kg)
Diesel	Truck	530
	Bus	1510
	Minibus	1000
	Jeep	62
	Tractor	102
	3-wheeler (D)	581
Gasoline	Taxi	1813
	Car	352
	3-wheeler (P)	788
	2-wheeler	451

6.6 Future Vehicle Emissions

Emission from the vehicles is dependent on the operating characteristics of the vehicle and number of vehicles operating on the fleet. Emission factors which are necessary for the emission calculation may change as time and other driving variables change. Emission factors change not only with time but also with quality of fuel, design of vehicle, road conditions and driving habit of the driver. However, same emission factors are used here for estimating the future emissions in the Valley.

6.6.1 Operating Characteristics

Vehicle operating characteristics such as specific fuel consumption, operation hours, speed etc. may change with time. It is assumed for the purpose of this study that these factors remain unchanged over time as it is not expected to change such variables drastically in the countries like Nepal. The same vehicle characteristics are used for the prediction of future emission in the Kathmandu Valley.

6.6.2 Operating Vehicles

Vehicle forecast provides information on the number of vehicles registered up to the period of various future years. Because base information are derived from the number of vehicles registered in the past years. The number of operating vehicles are estimated from the scrapping rates . The operating number of future cars are divided into the private car, jeep and taxis. About 56 per cent of registered taxis are found to be operating in the Valley. Numbers of private cars and jeeps are considered in the ratio of 80 and 20. Number of future operating vehicles are shown in Annex 6-2.

6.6.3 Emission in 2000, 2005, 2010, 2015 and 2020

There were about 31 thousands tons of pollutants emitted by the transport sector in the Kathmandu Valley in 1996. It is expected to reach to 53 thousands ton in the year 2020. Exhaust emission of TSPs is expected to increase by 1.36 per cent per year. Similarly, CO is expected to increase by 2.5 per cent per year, HCs 1.8 per cent per year, NOx 0.88 per cent per year, SO_2 1.65 per cent per year and Pb 2.9 per cent per year. There will be overall increase of the level of pollutants at the rate of 2.2 per cent per year. Table 6.10 illustrates the emission level of different pollutants in various years in the Kathmandu Valley. Details of the calculation are given in Annex 6-3.

Table 6.10 : Vehicle Emissions for the Future (tons)

Year	TSPs	CO	HCs	NOx	SO_2	Pb
2000	539	20898	10284	1998	151	5
2005	571	23507	11247	2044	161	5
2010	609	26561	12314	2125	174	6
2015	657	30186	13513	2257	192	7
2020	717	34496	14852	2456	215	8

The above Table exhibits that the emission level will be about 53 thousand tons in year 2020 which is about 70 per cent higher than the present level.

6.6.4 Sensitivity Analysis

Sensitivity analysis is conducted here too to see what will happen if there experience the slight change in vehicle operating characteristics which affect the emissions level. The emission level is analyzed with the ±5%, 10% and 15% change in vehicle kilometer in future. Table 6.11 shows the results of the sensitivity analysis.

Table 6.11: Emissions at Different Vehicle Kilometer in Future.

Year	Emission at Different Vehicle Kilometer (vkm)			
	-5%	+5%	+10%	+15%
2000	32182	35569	37263	38957
2005	35659	39413	41290	43166
2010	39701	43880	45970	48059
2015	44471	49152	51492	53833
2020	50107	55381	58018	60655

It can be concluded from the above table that the emission level of 2020 will be within the range of about 50 to 60 thousand tons of the pollutants. This clearly indicates that emission level of the vehicular pollution will be almost double by the period of 2020 in the Kathmandu Valley.

6.6.5 Emission Considering Three-wheelers

Despite the popularity, 3-wheelers are phasing out from the Kathmandu Valley because of the government regulation on banning further registration in the Valley. It is interesting to see what would happen if the present growth rate of 3-wheelers were allowed to register and operate in the Valley. An attempt has been made to calculate the emission level in the Valley with the unregulated government policy on 3-wheelers. Table 6.12 shows the emission level considering the unregulated 3-wheeler in the Valley.

Table 6.12:- Level of Pollutants with Unregulated 3-wheelers (ton)

Year	TSPs	CO	HCs	NOx	SO_2	Pb	Total
2000	577	21571	10701	2289	161	5	35305
2005	637	24683	11975	2542	178	6	40023
2010	681	27871	13126	2657	193	7	44534
2015	732	31580	14377	2813	211	8	49720
2020	798	35928	15739	3020	235	9	55724

This result show that banning of 3-wheelers is able to reduce emission level of 2000 by 4.22 per cent. Similarly, this action has a potential to reduce emission by 6.6 per cent in 2005, 6.56 per cent in 2010, 6.21 per cent in 2015 and 5.6 per cent in 2020.

6.7 Greenhouse Gas Emission

Transport sector emits not only local pollutants, but also emits a large amount of greenhouse gases that cause global warming. There are a large numbers of greenhouse gases In this study, an attempt has been made to estimate the amount of greenhouse emissions, mainly CO_2, CH_4 and N_20 from the transport sector in the Kathmandu Valley.

There are various factors suggested by the different researchers for the estimation of the GHGs. Emission factors mentioned in Scholl et al. (1996) and Piccot et al. are used here to estimate the GHGs emission.

6.7.1 Gasoline Demand Estimation

A simple model which is based on the vehicle stock, specific fuel consumption and yearly kilometer traveled is used here.

$$G = \Sigma \frac{Mi * Si}{MPGi} \quad \text{(Eq 6-1)}$$

where,

G = Gasoline Demand

Mi = Yearly Mileage (km/year)

Si = Number of vehicles of type i

MPGi = Specific fuel consumption (km/liter)

The amount of diesel and gasoline consumption for the year 1996 is given in Table 6.13.

Table 6.13: Estimation of Diesel and Gasoline Consumption in 1996

Fuel	Vehicle	Si	Mi(km)	MPG (km/liter)	G (kl)	GJ
Diesel	Truck	720	15,840	5	2,280	84,350
	Bus	613	45,150	3.5	7,907	292,427
	Minibus	745	54,335	4.3	9.414	348.130
	Jeep	4,373	8,740	10	3,822	141,338
	Tractor	732	16,414	5.7	2,108	77,954
	3-W	1,200	31,584	11.2	3,384	125,140
Total					28,916	1069,339
Gasoline	Taxi	2,027	24,720	10	5,011	163,058
	Car	15,462	4,800	10	7,422	241,511
	3-W	1,800	21,150	15	2,538	82,587
	2-W	39,174	10,351	45.4	8,932	290,648
Total					23,903	777,804

Nepal Oil Corporation distributed motor gasoline and high speed diesel 41,191 kiloliter and 250,504 kiloliter respectively in 1996, out of which about 35,000 kiloliter of motor gasoline and 52,530 kiloliter of high speed diesel were consumed in the Valley (Khadka, 1996). Apart from the transport sector, motor-gasoline and diesel are being used in other industrial and commercial sectors. Therefore, it can be inferred that the Valley consumed about 70 per cent motor gasoline and 55 per cent diesel oil in transport sector in year 1996. It is mentioned in the bulletin of NOC that gasoline consumption is about 28,000 kiloliter per year in the Valley (Upadhyaya, 1996b). This statement substantiates the above finding on the amount of gasoline consumption in the Valley.

Future gasoline demand is estimated applying the same approach as taken in calculating the gasoline demand for the year 1996. Table 6.14 shows the future petroleum oil demand.

Table 6.14: Future Gasoline Demand of Transport Sector (kl)

Fuel	Year				
	2000	2005	2010	2015	2020
Diesel	29,641	30,569	31,705	33,336	35,715
Gasoline	26,065	29,343	33,213	38,012	44,076

6.7.2 GHGs Estimation

Transport sector emitted about 125 thousands ton of CO_2 equivalent GHGs emission in the Valley last year. Burning of diesel oil contributes about 63 per cent GHG emissions of transport sector in the Valley.

The following Table 6.15 shows the GHG emission from the different types of vehicles in the Valley.

Table 6.15: GHGs Emission From Transport Sector

Vehicle	Emission Factor(g/GJ)			Emission (Ton)			Total CO_2 equivalent
	CO_2	CH_4	N_2O*	CO_2	CH_4	N_2O	
Light Duty Gasoline	54.900	36		42,702	28		46,005
Gasoline			10			5.7	
Light Duty Diesel	73,750	2		51,076	1.38		79,430
Heavy Duty Diesel	73,300	8		27,618	3.01		
Diesel			10			1.7	
Total				121,396	32.39	7.4	125,435

* mg/km GHG potentail CH4 = 63, N2O = 270 (Wade, et al.,1994)

Light duty gasoline vehicles emitted about 46 thousands tons of CO_2 equivalent green house gas in the Valley in 1996. Diesel vehicles had the maximum share of GHGs emission on the total emission of more than 125 thousands ton in the Valley.

Future GHGs emission is estimated by taking same approach as taken above. Table 6.16 exhibits the future GHGs emission from the transport sector in the Valley.

Table 6.16: Future GHGs Emission from Transport Sector(ton)

Year	CO_2	CH_4	N_2O	CO_2 Equivalent
2000	127,225	35.1	7.9	131,569
2005	135,597	39.3	8.5	140,368
2010	145,592	44.06	9.3	150,879
2015	158,585	50.14	10.2	164,498
2020	175.872	57.87	11.37	182,588

6.8 Impacts on Air Quality

The following table exhibits the estimated values of the future atmospheric concentration of pollutants. The details of calculations are shown in Annex 6-4.

Table 6.17: Estimated Atmospheric Concentrations of Pollutants

Year	Pollutants	Concentration (ug/m^3)	
		minimum	maximum
1996**	TSPs	84	775
	CO*	10	10
	SO_2	13	150
	Pb	0.18	053
2000	TSPs	87	806.01
	CO*	10.84	10.84
	SO_2	13.54	156.20
	Pb	0.225	0.6625
2005	TSPs	91.57	853.3
	CO*	12.06	12.06
	SO_2	14.43	166.55
	Pb	0.225	0.66
2010	TSPs	97	909.4
	CO*	13.5	13.5
	SO_2	15.6	180
	Pb	0.27	0.795
2015	TSPs	103.86	980.3
	CO*	15.20	15.2
	SO_2	17.21	198.6
	Pb	0.315	0.93
2020	TSPs	112.43	1068.89
	CO*	17.23	17.23
	SO_2	19.27	222.41
	Pb	0.36	1.06

(* Concentration if CO is given mg/m^3 ** Present Concentration)

The above results illustrate that the concentration of CO will cross the WHO standard of 10 mg/m^3 (for eight hour concentration) by 2000 in the Valley. The concentration of other pollutants in low traffic areas may not exceed the WHO standards (TSP 150 ug/m^3, CO 10 mg/m^3, SO2 125 ug/m^3 and lead 1.0 ug/m3) in 2020, however, at heavy traffic areas, the concentration of pollutants have already exceeded the WHO standards and the situation will be even more severe in the years to come. The concentration of lead pollutants will exceed the WHO standard by 2020 in most of the traffic areas in the Valley.

6.9 Conclusion

Transport sector contributed about 31 thousand tons of air pollutants in 1996. According to the vehicle forecast, vehicular pollutants are expected to reach 53 thousand tons in 2020. There will be an overall 2.2 per cent increase in vehicular air pollutants in the Valley. GHGs emission from the transport sector were also significant, 125 thousand tons of CO_2 -equivalent in year 1996. The air quality of the valley will further deteriorate due to increasing emissions in future. The CO concentration will cross the WHO standard and the lead concentration will exceed the WHO standard in most areas in year 2020. The concentration of other pollutants may not exceed the WHO standard for low traffic and residential areas by 2020. However, for the heavy traffic areas, the situation has already become bad, will be further worsen.

Chapter 7

Economics of Vehicle Operation and Pollution

7.1 Background

This chapter identifies the vehicle operational cost on life-cycle basis. Life-cycle costs for different types of vehicles are calculated both from individual and national perspective. This chapter estimates also the costs of pollution reduction with the application of the alternative fuel vehicle options. The costs of pollutants in term of cents per kilometer and break-even gasoline prices are also estimated.

7.2 Cost Determinants

Economics of vehicle operation is dependent on many factors. Some of the major factors are given below.

7.2.1 Vehicle Price

There are various types of vehicles available in the Kathmandu Valley. Indian made vehicles are quite popular and are, also, cheaper compared to other imported vehicles from third countries. Mostly buses and trucks are Indian made. However, the government owned public undertaking operates the buses which are Japan made. Passenger cars and taxis are imported from different countries. Mostly, 2- and 3-wheelers are Indian made. The market prices of some of the vehicles which are quite popular in the Valley are shown in Annex 7-1.

7.2.2 Government Duties

Custom duties for passenger vehicles are dependent on sitting capacity. Vehicles with higher seating capacity are taxed lower compared to the vehicles with the lower seating capacities. Custom duties for the vehicles range from 20 per cent to 110 per cent on their initial price. Tax on cars is about 110 per cent of thier CIF cost and that on motorcycle is about 40 per cent. Sales taxes for all the vehicles are 15 per cent but there is a provision for a concession of 50 per cent and one third for the vehicles operating on diesel and gasoline fuel respectively.

Imported electric vehicles are subject to pay 10 per cent customs duties and no sales tax. There is only one per cent customs duties and no sales tax on on the import of chassis or engine fitted with chassis including parts of 3-wheelers that operate only with electricity, gas, or battery.

The details of current import duty are shown in Annex 7-2.

7.2.3 Operating Costs

In actual practice, the vehicle operating costs vary significantly in different driving conditions and driving practice. Table 7.1 exhibits operating costs of various type of vehicles running in the Valley based on vehicles survey by the author.

Table 7.1: Annual Vehicle Running Costs in the Valley

Vehicle	Fuel		Lubricant		Repairing		Regular Servicing	
	NRs.	US $	NRs.	US $	NRs.	US $	NRs.	US $
Bus	180011	3172	30720	541	21200	374	20500	361
Jeep	26700	470	11844	209	7081	125	8250	145
Truck	69759	1230	27439	484	17666	311	57066	1006
Minibus	199987	3524	30240	533	9100	160	10500	185
3-wheeler (P)	34050	600	7200	127	7400	130	7833	134
Taxi	84684	1492	14400	254	7648	135	12214	215
Car (P)	54821	966	15000	264	4352	77	8380	147
Car (D)	22587	398	15000	264	4352	77	8380	147
Motorcycle	7491	132	3024	53	1065	18	1530	26
Tractor	40200	708	13344	235	13900	245	32500	573
3-wheeler (D)	37512	661	9684	171	6964	123	9271	163

Source : Field Survey by the Author (P - Petrol/gasoline, D - Diesel)

The cost of tyre is included in expenditures on repairing and regular servicing. Operating costs for electric vehicles, mainly trolley and 3-wheelers, are obtained from their respective organizations.

7.2.4 Vehicle Life

In this study, operational life of 25 years is considered for the private passenger cars and 20 years for other gasoline and diesel vehicles. Like -wise the life period for the electric vehicles, Trolley and Safa tempo, is considered 30 years. The operational periods which are considered here are based on the actual working conditions of vehicles in the Valley. Trolley buses are operating since their establishment and are expected to run even more[1]. In some cases, trolley bus can be operated for more than 37 years before either being replaced or rebuilt (NZERDC, 1981). Since there are no major moving components, Safa Tempos are expected to operate more than 30 years with replacement of batteries time to time[2].

1 Devkota, S. , Trolley Bus Offoce - personal communication.
2 Shrestha, B. R., NEVI- personal communication.

7.3 Life- Cycle Cost

7.3.1 Existing Operating Condition

There are basically four type of fuels that are being used in transport sector in the Valley. These are diesel, gasoline, electricity and LPG. The life-cycle costs of the vehicles operating in the Valley are calculated using the practical operating characteristics of the vehicles. A slight adjustment is done in order to obtain the costs comparable among the similar vehicles, such as diesel , electric and LPG 3-wheelers etc. Discount rate of eight per cent is used to obtain the present value for the expenditures made in the future.

The life-cycle costs of different types of vehicles in the valley are given in Table 7.2. Further details related to the costs are shown in Annex 7-3.

Table 7.2: Life Cycle Costs for the Vehicles in the Valley

Fuel Type	Vehicle	Life Cycle Cost		Existing Fare
		cent/km	NRs./km	NRs./km
Diesel	Bus	17.04	9.67	
	Minibus	14.62	8.3	
	Car	12.71	7.21	9.00
	3-wheeler	5.14	2.91	
Gasoline	Car	13.85	7.85	10.00
	3-wheeler	8.35	4.75	6.50
	2-wheeler	4.05	2.3	
Electricity	Trolley	28.54	16.2	21
	Minibus	15.78	8.95	
	3-wheeler	10.13	5.75	9.00
LPG (3-wheeler)	Taxi	6.95	3.95	6.5
	Fixed Route	5.25	2.97	

Diesel car operates on slightly lower cost than that of the gasoline car. Despite the slightly higher vehicle cost in case of the diesel car, gasoline car costs more on life-cycle basis because gasoline costs higher than diesel in the Valley. Electric Vehicles, except minibus seem to be quite expensive compared to their gasoline counterparts. Electric minibus, which seems to be quite competitive per kilometer cost basis , can not accommodate as many persons as the gasoline minibus can. The electric minibus that is considered here has the seating capacity of 14 persons whereas the average designed capacity of the gasoline minibus is 30 persons per trip. Life cycle cost of the trolley bus is the highest in the Valley. The converted 3-wheelers cost almost double to that of the diesel wheeler. LPG vehicles seem to be quite competitive to their respective counterparts, 3-wheeler (P) to LPG taxi and 3-wheeler (D).

The life-cycle costs, thus obtained above, seem to lie within the practicable range of vehicle's operation. The existing fare of the vehicles in public services are very much close to the life-cycle costs thus obtained. In Kathmandu, taxi charges nine to ten rupees per kilometer depending on the types of taxis. The life-cycle cost for the car obtained here is about seven rupees per kilometer. Similarly the gasoline 3-wheelers, operating as a taxi, charge 6.50 rupees per kilometer of distance covered. At the present rate, trolley bus earns approximately 21 rupees per kilometer, and the life-cycle cost of 16.20 rupees per kilometer falls under the practicable range. The converted electric 3-wheeler charges nine rupees per kilometer in the Valley.

7.3.2 National Perspective

Price of Vehicles, Battery, Fuels and Lubricants

The government duties, taxes, registration and other in-country costs are deducted from the initial price of vehicles, batteries and lubricants in order to obtain the price from national perspective.

The government has control on the price of electricity and petroleum products in Nepal. Gasoline costs NRs. 34 per liter whereas the cost of diesel is NRs. 14 per liter. Similarly LPG costs about NRs. 26 per liter. Gasoline is taxed NRs. 9,000 per kiloliter and similarly diesel NRs. 1,155 per kiloliter. LPG is taxed 10 per cent on its initial cost. However, under the directives of the government, Nepal Oil Corporation, further, set the price of the petroleum products for the consumer use. The boarder prices of the different petroleum products are not readily available accurately.

The boarder prices for the petroleum products are, hence, estimated from the past information on import of petroleum products and payment made by the country for such import. Table 7.3 shows the quantity of petroleum products imported and its price paid by the country in past six years.

Table 7.3: Quantity and Price of Petroleum Products Import

Year	Quantity (kiloliter)	Price (NRs. Million)	Price per Liter
1994	516331	5344	10.26
1993	446749	4971.3	11.12
1992	420974	4108.6	9.75
1991	363935	4411.2	12.12
1990	231847	3025.6	13.05
1989	219980	2178.2	9.91

Source: MOF (1995)

There are no big variations on the price among the different petroleum products in international energy market. The economic costs of the petroleum products are taken NRs. 12 per liter for gasoline, diesel and LPG in Nepal for the year 1996.

Price of Electricity

Electricity costs for the transport sector has been used here for calculating the life cycle cost from national perspective.

Life-Cycle Costs

The life-cycle costs of the vehicles are obtained by adjusting the market price into the national shadow price of vehicles, fuels and other expenses. Fifty per cent of the operation and maintenance costs are considered as local costs and remaining are foreign costs. Discount rate of 10 per cent is used to obtain the present value of the future expenditures. The results presented in Table 7.5 exhibits, however, the result of the life-cycle costs calculated considering different discount rates.

Table 7.5: Life-Cycle Costs of Vehicles From National Perspective

Fuel Type	Vehicle	Life Cycle Cost					
		at 8 % discount		10 % discount		12 % discount	
		cent/km	RS/km	cent/km	Rs/km	cent/km	Rs/km
Diesel	Bus	12.82	7.28	13.42	7.62	14.18	8.05
	Minibus	11.28	6.40	11.76	6.67	12.38	7.03
	Car	6.178	3.51	6.7	3.80	7.25	4.11
	3-wheeler	3.69	2.09	3.79	2.15	3.94	2.24
Gasoline	Car	5.6	3.18	6.04	3.43	6.5	3.69
	3-wheeler	3.97	2.25	4.09	2.32	4.26	2.42
	2-wheeler	1.85	1.05	1.95	1.11	2.06	1.17
Electricity	Trolley	20.9	12.04	23.49	13.54	26.15	15.07
	Minibus	13.89	8.00	14.92	8.60	16.02	9.23
	3-wheeler	8.99	5.18	9.24	5.32	9.51	5.48
LPG (3-wheeler)	Taxi	3.26	1.85	3.47	1.97	3.71	2.11
	Fixed Route	4.74	2.69	5.1	2.89	5.25	2.98

It can be concluded from the above life-cycle costs analysis that electricvehicles cost more than petroleum vehicles Diesel powered 3-wheelers operating on the fixed route are found to be the least cost options. LPG run 3-wheelers are slightly expensive than the diesel powered 3-wheelers. Electric 3-wheelers (popular Safa Tempos) are quite expensive on comparison to diesel and LPG run 3-wheelers. Diesel cars cost slightly more than the gasoline cars in their lifecycle basis.

7.4 Costs of GHGs Emissions Reduction

Table 7-6 exhibits the incremental and GHGs emission reduction costs by using electric bus instead of diesel bus, electric minibus instead of diesel minibus and electric tempo (Safa Tempo) instead of diesel tempo.

Table 7.6: Incremental and GHGs Emission Reduction Cost

Vehicle		Cost	
Reference	Candidate	GHGs Emission Reduction ($/ton)	Incremental (cents/km)
Diesel Bus	Trolley	101	11.50
Diesel Minibus	Electric	28.5	1.16
3-W (D)	Electric	185	4.99

The incremental costs for replacing the diesel vehicles with the electric range from 1.16 cents per kilometer for minibus to 11.50 cents per kilometer for bus. Three-wheeler has the moderate incremental cost, 4.99 cents per kilometer. The costs of CO_2 reduction per ton are US$ 28.5 from the electric minibus, US$ 101 from the trolley bus, US$ 186 from the electric 3-wheeler and US$ 607 from the electric car.

7.5 Break-Even Gasoline Price

Break-even gasoline price is the gasoline price (excluding retail taxes) at which the lifecycle cost of gasoline powered internal combustion vehicle equals the lifecycle cost of the alternative vehicle. Table 7.7 exhibits the break-even gasoline price for the alternative fuel vehicles used in this study i.e., electrical and LPG powered vehicles. The reference vehicles used here are gasoline and diesel powered vehicles.

Table 7.7 : Break-even Gasoline Price (cent/liter)

Fuel Type	Vehicles			
	Bus	Minibus	3-W (Fixed Route)	3-W (Taxi)
Petroleum	21.15	21.15	21.15	21.15
Electric	56.84	39.84	82.74	-
LPG	-	-	17	36.20

The break-even gasoline price for the electric trolley bus is about three times more than the price of the gasoline. Like-wise, that of battery powered minibus and 3-wheeler are about two times and four times more than gasoline price. The LPG Tuk-Tuk running on the fixed route operates in the lower cost than that of the gasoline powered 3-wheeler.

7.6 Conclusion

Electric vehicles, except electric minibus. seem to be quite expensive compared to their gasoline counterparts. Life-cycle cost for the trolley bus was the highest and the lowest for the motorcycles. LPG 3-wheelers were slightly expensive than diesel powered 3-wheelers but less expensive than the electric Safa tempo. The GHGs emission reduction can be achieved at the cost ranging from about 28 $/ton to 600 $/ton depending on the candidates vehicles used. Break even gasoline price for the electric vehicles and LPG taxi are higher for the vehicles operating on petroleum but lower for the LPG vehicles operating as a taxi.

Chapter 8

Electrical Vehicle and Its Impacts

8.1 Background

This chapter concerntrates on the eletric vehicle (EV) program and analyzes its technical feasibility in the context of the Valley. Three scenarios are developed to analyze the likely-impacts of EVs on emission, air quality, petroleum fuel displacement, and lead disposal.

8.2 Electric Vehicle Program

8.2.1 Trolley Bus

The construction work for the infrastructure of Trolley bus service was initiated in 1973 and was completed in 1975. The Trolley bus service was started its operation with 14 buses having the capacity of 63 person (35 sitting and 28 standing). Now there are altogether 24 buses operating on the route. The Trolley bus service is being managed by Nepal Transport Corporation, a government owned transport undertaking, in Nepal.

8.2.2 Safa Tempo

Safa (clean) Tempo is the name given to electric 3-wheelers operating on charged batteries. Electric vehicle industry in Nepal is the result of a collaboration involving USAID/Nepal, the U. S. Embassy, the US-Asia Environmental Partnership (US-AEP), His Majesty's Government of Nepal, Global Resources Institute (GRI), an American non-governmental organization, and Nepali private firms and individuals.

In 1993, US-AEP provided a grant to GRI to convert one diesel 3-wheeler into the electric. Following a successful demonstration, USAID/Nepal and US-AEP provided additional funding to develop seven more electric 3-wheelers and to demonstrate the technical and economic viability of operating the vehicles for public transportation. In a six month period, eight Safa Tempos had carried over 200,000 passengers and traveled over 175,000 kilometers (TRN, 1996). This demonstration sparked the interest of private industry.

On February 1996, the keys to the fleet of seven electric tempos were passed from GRI to the owners of the Nepal Electric Vehicle Industry (NEVI). NEVI was established on March 1996. It has developed two 12 -and 8-seater Safa Tempos prototype models. It is planning to develop a 4-wheeler electric prototype for the passenger service. Including the ten 3-wheelers developed by NEVI, now there are altogether 17 electric vehicles providing passenger service in the Valley. These vehicles are presently operating on four specified routes in the Valley. There are some organization like the Danish Embassy , SAPROS Foundation, and BP Koirala Indo-Nepal Academy which are owning and using the converted electric 3-wheelers for transporting their staff in the Valley.

In addition to NEVI, there is one more electric vehicle company (EVCO) which has been registered and started recently manufacturing the electric vehicles. It has, so far, developed seven electric vehicles for public transport of eleven people and has displayed these vehicles for sale[1].

8.3 Technical Feasibility of EVs

The technical feasibility for the use of electric vehicles in the Valley depends on two major factors. The first one is whether the electric power generation system has sufficient spare capacity to recharge EV batteries without building new power stations or disturbing the present generation capacity. Another issue is whether the current travel patterns in the Valley are compatible with the characteristics of electric vehicles.

8.3.1 Present Generation Capacity

The present electricity generation system has an installed capacity of 282.214 MW of which about 275 MW is required to meet peak power demand. In Integrated Nepal's Power System (INPS), 91 per cent electric power come from hydropower plants. Current annual energy generation capacity is about 1261.76 GWh and generates about 937.494 GWh (NEA, 1996). The daily load is the highest during the day and the evening, and minimum during the night. There is about only 137 MW capacity required to meet off-peak hour power demand.

The following calculation exhibits the number of electric vehicles that could be accommodated in the existing system without disturbing the present generating capacity. This calculation is based on the assumption on vehicle charging during the off-peak period at night (mostly between 11 p.m. to 7 a.m.).

$$\textit{Number of vehicles can be charged (N)}^{2} = \frac{n * P * H}{M * E} \qquad \text{(Eq. 8.1)}$$

where,

n = efficiency of lead-acid battery,
P = power available off-peak (kW),
H = battery charging hours (hour),
M = daily average distance covered (km), and
E = average efficiency of the electric vehicle (kWh/km).

Efficiency of the lead-acid battery is 75 per cent in general case (Hamilton, 1980). The battery charging duration is eight hours and the average distance covered is 40 km. The average efficiency of the electric vehicles is mentioned differently in different publications. In actual Kathmandu condition, Safa Tempo requires charging at the rate of 0.15 kWh/km[3].

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1 Thapa, S.,EVCO- personal communication
2 Source:- McGann (1994)
3 Shrestha, B. R. , NEVI- personal communication

However, OECD(1993) mentioned the average electricity use of 0.40 kWh/km for low performance EV and 0.15 kWh/km for high performance EV. Renne et al. (1994) quoting Canadian Energy Research Institute(CERI) provided the energy efficiency for the electric vehicle as 0.13, 0.165 and 0.205 kWh/km for the low performance, base and high performance subcompact car. We here use the average energy consumption of 0.40 kWh/km to estimate the number of vehicles that could be operated using the off-peak hour power supply.

Following Equation 8.1, the spare off-peak capacity of the system could charge about 50 thousands electric vehicles. Current NEA forecasting of future power demand assumes that there will be no change in industrial and domestic power demand other than a small increase. This means that unless there is a drastic change of life-style in future, daytime and evening power demand will always be greater than the overnight off-peak power demand. Note here that though Nepal has seasonal problems with residential power distribution and supply at peak periods, there are adequate supplies for off-peak power supply. However, if EVs appear on Kathmandu roads in significant numbers, then their recharging by the power system overnight will constitute a steady base load, which in turn would affect the daily loading curve.

8.3.2 Driving Pattern

The driving range of the EV is limited by the practical difficulty of storing large amounts of electrical energy compared with liquid fuels. However, many trips are short and well within the driving range of EVs in the Valley as illustrated in Table 5.5, i.e., many vehicle owners or drivers might be driving less than 40 kilometer of range per day and many even less.

The Valley is relatively flat and distance traveled is quite short. The speed of the vehicles is also quite low (30 to 40 km/hr on an average) which would suit electric vehicles well.

8.3.3 Technical Market Potential

Kathmandu is especially suited for electric vehicles in terms of its driving patterns and geo-physical characteristics and many people have mentioned that it could become a model for the rest of the world. The diesel powered 3-wheeler (Vikram Tempo) has a reputation of being one of the worst polluters in Kathmandu and the advocates proclaim that it should be among the first vehicles to be converted.

Battery operated buses are being introduced in the U. S and are operating in their fleet in some areas. India has also been operating electric powered buses. Bharat Heavy Electrical Ltd. (BHEL) has produced electric buses for 12 years. Shaja Yatayat[4] is considering to add some electric buses on its passenger service in the Valley. This could be successfully operated

[4] Satyal, M. R. , General Manager, Shaja Yatayat - personal communication.

if the government allows the private parties or the Shaja Yatayat to fix the fare on actual cost-basis.

A variety of electric vehicles that serve the transportation needs of the Valley resident. These include electric 3-wheelers to replace the diesel and gasoline 3-wheelers. electric shuttle buses, electric minibuses, electric 3-or 4-wheelers for cargo, electric delivery vans, electric courier vehicles; and hybrid trolleys which could allow the trolley buses to use overhead wires where they are available and to extend their routes through the use of battery operated power.

Table 8.1 shows the required number of future operating buses, minibuses, 3-wheelers(D), cars, taxis and 3-wheelers (P) in the Valley. The figure s could also serve as the maximum number of electrical vehicles that could be introduced in the valley purely from the technical perspective.

Table 8.1: Maximum Substitution Potential of EV

Vehicle	Substitution Potential of EV in the Valley				
	2000	2005	2010	2015	2020
Bus	27	66	112	178	275
Minibus	13	13	13	13	13
3-wheeler	163	366	528	660	765
Car	1396	3257	5226	7327	9524
Taxi	454	1186	2133	3358	4945
3-wheeler (P)	245	508	793	989	1148
Total	2298	5396	8805	12525	16670

8.4 EVs Penetration Scenarios

It is very difficult to know precisely how many electrical vehicles will be coming into the operation in future. However, three types of scenarios are developed here to analyze the likely impacts of electrical vehicles on emissions and economics of the vehicular operation. These are;

- Scenario I,
- Scenario II, and
- Scenario III

8.4.1 Scenario I

Here it is assumed that all the new vehicles entering into the Valley would be electric. All the new vehicles entering the vehicle fleet (except the truck, tractor, and motorcycle) as shown in Table 8.1 are assumed to be electric in this case.

8.4.2 Scenario II

In this scenario, it is assumed that if penetration of EV is started from 1997 onward; then by 2000, it is assumed to be 5 per cent EVs to the total vehicle fleet. By 2005, the number will be 10 per cent, and likewise 15 per cent, 20 per cent and 25 per cent by 2010, 2015 and 2020 respectively. The numbers of future electric vehicles, according to this scenario, are shown in Table 8.2.

Table 8.2: Number of Electric Vehicles According to Second Scenario

Vehicle	Substitution Potential of EV in the Valley in Year				
	2000	2005	2010	2015	2020
Bus	2	7	17	36	69
Minibus	1	2	2	3	4
3-wheeler	8	37	80	132	192
Taxi	22	118	320	672	1236
Car	76	325	828	1465	2381
3-wheeler (P)	12	50	118	198	287
Total	115	539	1365	2506	4169

8.4.3 Scenario III

This scenario is based on the past trends of electric vehicle development and the commitment of the main actors in the field of transport planning in the country. NEVI has recently added eight new and improved Safa Tempos to the existing fleet and is operating a battery charging cum exchange station. The Visit Nepal Year Secretariat, Ministry of Tourism, has set target of promoting the fielding of 300 EVs in Kathmandu Valley by 1998 (Sherchan, 1997). The Royal Danish Government is offering to provide substantial funds to assist in the conversion of 3-wheelers into electric and to create the ancillary infrastructure required for the industry in Nepal (Sherchan 1997). His Majesty's Government of Nepal has, also, taken important measures in reducing customs duties on EVs and its components.

The electricity operated buses and minibuses are also likely to get breakthrough in the Valley in years to come. Because there exist few prospects for further addition of trolley bus in the vehicle fleet because it is managed by government owned corporation, and which was able to earn a small profit out of the trolley bus service in the valley last year.[5] Another major transport cooperative -- Sajha Yayatat-- has been considering to start electric minibus service in the Valley.

Electric passenger car could be viable as second cars among multicar households and in other limited agencies. However, most of the car owners own a single car in the Valley and it is too early to expect them to go for the electric car. Table 8.3 exhibits the number of electric vehicles according to the third scenario developed in this study.

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5 Devkota, S., Trolley Bus Office- personal communication

Table 8.3: Number of Electric Vehicles According to Scenario III

Vehicle	Substitution Potential of EV in the Valley				
	2000	2005	2010	2015	2020
Bus	2	7	17	36	69
Minibus	1	2	2	3	4
3-wheeler	300	400	500	600	700
3-wheeler (P)	25	50	75	100	150
Total	328	459	594	739	923

The penetration rate for the bus and minibus is taken same as Scenario II. For 3-wheelers, the penetration rate is based on the target set by the government and the Royal Danish Enbassy in Nepal and also based on past development trends.

Penetration number of EVs under different scenarios in different years are shown in Annex 8.1.

8.5 Impacts on Emissions and Economy

The benefits of EVs are examined by estimating the emissions that would be avoided when EVs displace conventional vehicles in the Kathmandu Valley.

8.5.1 Emission Reduction Potential

Since hydro power provides the major share of electricity in Nepal, electrical vehicles emit no air pollutants in net terms. Table 8.4 exhibits the amount and the corresponding percentage reduction of total pollutants in the Valley for the scenarios.

Table 8.4: Emission Reduction Potential in Different Scenarios

Year	Total Emissions (ton)	Emission Reduction in %					
		Scenario I		Scenario II		Scenario III	
		ton	%	ton	%	ton	%
2000	33,875	1,656	4.88	83	0.24	193	0.57
2005	37,536	4,023	10.7	402	1.07	284	0.76
2010	41,790	6,821	16.3	1,039	2.48	377	0.90
2015	46,811	10,113	21.60	2,024	4.32	485	1.036
2020	52,744	14,097	26.70	3,525	6.68	633	1.20

This table clearly illustrates that Scenario I has, obviously, the largest potential to reduce conventional pollutant emissions in the Valley. This scenario is the most optimistic among the three and also unlikely to take place in near future. Scenario II is moderate and could take place if the government takes a determined approach for the electrical vehicle introduction in the country. However, this scenario is not adequate enough to reduce the air pollutants remarkably from the transport sector in the Valley. Scenario III is the most likely to occur among the three. It has the least emission reduction potential and its impact on the total emission reduction will almost be negligible.

8.5.2 Air Quality

Table 8.5 presents the impacts on air quality from the electrical vehicles introduction under Scenario I.

Table 8.5: Impacts on Air Quality According to Scenario I

Year	Pollutants Concentration)							
	TSPs (ug/m³)		CO (mg/m³)		SO_2 (ug/m³)		Pb (ug/m³)	
	min	max	min	max	min	max	min	max
1996	84	775	10	10	13	150	0.18	0.53
2000	84.57	780.9	10.24	10.24	12.91	148.96	0.18	0.53
2005	86	795.7	13.51	13.51	13	150	0.18	0.53
2010	88.4	820.8	11.00	11.00	13.17	152.06	0.18	0.53
2015	91.86	856.22	11.46	11.46	13.71	158.30	0.18	0.53
2020	96.3	902.00	11.98	11.98	14.43	166.55	0.18	0.53

The table exhibits that the concentration of air pollutants are likely to increase in both heavy and low traffic areas but at a slower pace. The CO concentrations which are now within the WHO standard, will exceed from the year 2000 onwards. The increase in CO concentration is justified with the increasing number of 2-wheelers. The concentration level of lead may not increase from the present level. TSPs and SO_2 concentration are already exceeded WHO standards and will further increase in future.

Table 8.6 shows the impacts under Scenario II. It can be seen that air quality is going to deteriorate further even after introducing electrical vehicles. The lead concentration is expected to increase further but will not exceed the WHO standard. Other pollutants the concentration of which has already reached an alarming level, will increase further.

Table 8.6: Impacts on Air Quality According to Scenario II

Year	Pollutants Concentration)							
	TSPs (ug/m³)		CO (mg/m³)		SO_2 (ug/m³)		Pb (ug/m³)	
	min	max	min	max	min	max	min	max
1996	84	775	10	10	13	150	0.18	0.53
2000	86.85	804.53	10.80	10.80	13.54	156.20	0.225	0.66
2005	91	847.36	11.92	11.92	14.25	164.50	0.225	0.66
2010	95.72	896.10	13.12	13.12	15.24	175.86	0.27	0.795
2015	101.43	955.17	14.46	14.46	16.50	190.34	0.27	0.795
2020	108.43	1027.54	15.92	15.92	18.02	207.93	0.315	0.93

Table 8.7 shows the impacts on air quality from the electrical vehicles under Scenario III. Though there would be a small reduction in pollutants, it won't be adequate for improving the air quality in the Valley.

Table 8.7: Impacts on Air Quality According to Scenario III

Year	Pollutants Concentration)							
	TSPs (ug/m^3)		CO (mg/m^3)		SO_2 (ug/m^3)		Pb (ug/m^3)	
	min	max	min	max	min	max	min	max
1996	84	775	10	10	13	150	0.18	0.53
2000	84.85	783.86	10.81	10.81	13.17	152.07	0.225	0.6625
2005	88.71	823.73	12.03	12.03	13.98	161.37	0.225	0.6625
2010	93.28	870.99	13.46	13.46	14.97	172.75	0.27	0.795
2015	99.28	933.02	15.15	15.15	16.31	188.27	0.315	0.9275
2020	107.42	1017.20	17.16	17.16	18.2	210.00	0.36	1.06

Based on the above discussion, it is clear that though the introduction of electrical vehicles will contribute to reduce the air pollutants in the Valley to some extent but it may not be sufficient to improve the air quality.

8.5.3 GHGs Emission

Table 8.8 shows the amount and percentage of GHGs emission reduction from the Valley after the introduction of electric vehicles under different scenarios. As can be seen, EV introduction would reduce the GHGs emissions ranging from 0.28 per cent to 5.09 per cent in year under different scenarios. Likewise 4.6 per cent to 27.8 per cent GHGs reduction would be achieved in 2020.

Table 8.8 : GHGs Reduction Potential

Year	Total Emission (ton)	Scenarios					
		I		II		III	
		ton	%	ton	%	ton	%
2000	131569	6708	5.09	372.2	0.28	2503	1.9
2005	140368	15469	11	1583	1.13	3559	2.5
2010	150879	25314	16.78	3851	2.55	4755	3.15
2015	164498	36809	22.37	7394	4.49	6299	3.82
2020	182588	50865.67	27.8	12754	6.98	8412	4.6

8.5.4 Petroleum Fuel Displacement

Nepalese electricity sector is hydro based and one of the major advantages of electric vehicles is to provide energy security to the country as EV can displace the imported fossil fuels used in transport sector. Table 8.9 exhibits the amount and percentage of petroleum products that will be displaced if EVs are used instead of conventional vehicles under the selected scenarios..

Table 8.9: Reduction of Petroleum Products By EVs (ton)

Year	Oil Consumption		Scenario I		Scenario II		Scenario III	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
2000	26041	29641	2137 (8.2)	973 (3.3)	107 (0.41)	60.9 (0.2)	35 (0.135)	884 (2.9)
2005	29343	30569	5212 (17.7)	2048 (6.7)	518 (1.76)	219.9 (0.72)	70 (0.24)	1243 (4.06)
2010	33213	31705	8899 (26.7)	3098 (9.7)	1355 (4.07)	470 (1.48)	105 (0.32)	1654 (5.21)
2015	38012	33336	13213 (34.7)	4322 (12.9)	2644 (6.9)	874 (2.6)	141 (0.37)	2194 (6.58)
2020	44076	35715	18415 (41.7)	5869 (16.4)	4603 (10.4)	1482 (4.15)	211 (0.47)	2914 (8.16)

(Note:- Values in parenthesis are in percentage)

8.5.5 Battery Disposal

Some previous studies found that EV use would have worse impacts on water quality and solid waste than would ICEV use. Deluchi et al. (1989) found that most of adverse impacts were caused by the manufacture or disposal of lead-acid and nickel-iron batteries. Among all of the EV components, the battery posses a problem regarding its disposal.

The amount of lead contained on lead-acid batteries reported by different authors in the literature shows variations. Streicher (1992) mentioned that of the total contents of lead-acid battery of 250 kg, the composition would be:

Lead	= 150 kg,
Plastic	= 13 kg,
Acid	= 75 kg, and
Others	= 12 kg.

Hamilton (1980) mentioned that about 22 kg of lead and 0.5 kg of antimony are required for the current golf-car battery per kwh of capacity (at the two hour rate of discharge !). The 1985 battery would require approx. 13 kg of lead and 0.2 kg of antimony per kWh of capacity, assuming a low-antimony design (Hamilton, 1980).

The Safa Tempos use the American golf-car batteries. It approximately contains 240 kg of lead per battery pack. The life of the battery is considered 80,000 km (range 80 km per charge and 1000 cycles at 80 DOD). If the vehicles cover about 25.000 to 30.000 kilometer per year, the battery pack will be disposed after three years.

If the electrical vehicles are introduced onwards 1997, then first set of batteries will be disposed in 2000. We follow the same scenarios of electrical vehicles introduction in the

Valley as we mentioned above. The amounts of lead that will be disposed from the expired battery pack are shown in Table 8.10.

Table 8.10: Amount of Disposable Lead (ton)

Year	EV Introduction Scenarios		
	I	II	III
2000	109	5.52	11.28
2005	368.88	31.2	33.36
2010	571.2	85.68	39.12
2015	875.04	165.36	53.28
2020	1237.68	280.56	73.2

More than 90 per cent of the lead-acid batteries used for purposes other than EVs are now being recovered to recycle all the lead, outer cases and electrolyte. It will be possible to recover and recycle used EV lead-acid batteries in a similar way. Asean Brown Beveri has expressed that 97.5 per cent of their component could be recycled (OECD, 1993).

8.6 Conclusion

Present surplus off-peak generation capacity could charge about 50 thousand electric vehicles in Nepal. Driving parameters and geo-graphical locations favor the electric vehicles in the Valley. According to Scenario III, no significant impacts are likely to occur on air quality, total emission, and oil displacement. There would be significant impacts on all these factors if EVs are introduced according to Scenario I which is also the least likely to occur.

Chapter 9

Emission Control Devices and Measures and Its Impacts

9.1 Background

Emission control through the use of devices and measures (ECD/M) is relatively new and not well known to many people. This chapter discusses various emission control devices and measures and their roles on emission reduction in the Valley. It also analyzes the impacts of ECD/M on the life-cycle cost of the vehicles.

9.2 Emission Control Devices and Measures

Emission control through ECD/M approach is relatively newer, not widely demonstrated. In Kathmandu, it is hardly known not only to the general people but also to the people who deal with automobile parts and run motor repairing services. In an answer to the question whether the drivers in Kathmandu Valley have a knowledge on emission control devices (ECD), more than 70 per cent respondents mentioned that they had never heard about such devices. Table 9.1 shows the level of knowledge of emission control devices of the drivers. The table indicates that drivers of the most polluting vehicles -- such as bus, truck, and tractor -- have no knowledge on ECD/M. More than 76 per cent car owners and 55 per cent of motorcycle owners also seem to be ignorant on the devices that control the vehicular emission.

Table 9.1: Respondent Knowledge of Emission Control Devices.

Respondent (Driver)	Sample Number	Response	
		Heard About ECD	Have not Hear About ECD
Bus	10	3	7
Jeep	16	3	13
Truck	15	0	15
Minibus	10	2	8
3-wheeler (P)	6	1	5
Taxi	35	1	34
Car	21	5	16
Motorcycle	116	52	64
Tractor	4	0	4
3-wheeler (D)	14	0	14
Total	247	67	180
%	100	27.1	72.9

Source: Field Survey by the author

With initiatives of few private organization, government and bilateral development organization, few pollution control devices and measures are, however, introduced and demonstrated in Kathmandu Valley. Basically, they are:

- Magnetizers
- Unleaded Gasoline
- Catalytic Converters
- Inspection and Maintenance

9.2.1 Magnetizers

A magnetizer which energies the fuel and air by inducing opposite magnetic charges on air and fuel line in automobile engine. By doing so, it facilitates perfect combustion of the fuel.

Magnetizers have been marketed in Nepal for about half a decade. One of the major users of this device is the Sajha Yatayat which was able to reduce smoke level of its buses from 60 HSU to 28 HSU using the magnetizer[1]. Similar improvements were also reported by the Royal Nepalese Army and the Telecommunication Corporation of Nepal (Commercial Brochure, Intercraft Nepal). Royal Nepal Academy of Science and Technology (RONAST) tested magnetizers in the Kathmandu road condition and reported that it reduced CO emission from 1.5 per cent to 1.2 per cent and HC emission from 1200 ppm to 700 ppm. This product was also tested and certified by the California Air Resources Board (CARB) in 1988 (commercial Brochure, Intercraft Nepal). Table 9.2 shows some test results on magnetizer on various types of vehicles.

Table 9.2 :- Magnetizer Emission Reduction Tests Results

Vehicle	HC		CO		Reduction %	
	Before	After	Before	After	CO	HC
Chevy 307, V8	774	580	0.06	0	25	100
91 Suzuki	170	100	1.6	0.15	41	91
Nissan SX	70	90	0.3	0.2	+29	33
88 Volkswagen	320	270	3.8	2.8	15	26
86 Mitsubishi	390	330	6.2	3.6	15	42
RONAST Test	1200	700	1.5	1.2	41	20

Source:- Intercraft Nepal and RONAST.

The magnetizer could reduce the smoke of diesel engine up to 80 per cent. In addition to emission reduction, it also economies the fuel by 20 per cent of diesel use and 35 per cent of gasoline use. Magnetizers are readily available in the Kathmandu market. The prices of the magnetizer used in different vehicles are given in Table 9.3.

[1] Karki, K., Shaja Yatayat- personal communication

Table 9.3: Price of Magnetizer in Kathmandu Valley

Vehicle	Price	
	NRs.	US $
Gasoline Car	9235	163
Diesel Car	10600	187
Truck/Bus	20763	366
2-wheeler	23025	406
3-wheeler (D)	8560	150
3-wheeler (P)	4975	88

Source: Inter Craft Nepal (1997)

9.2.2 Unleaded Gasoline

Unleaded gasoline has been introduced in the Kathmandu Valley since 1997. However, there is only one gas station that sells the unleaded gasoline in the Valley. The gas station is selling about 50 to 60 liters of unleaded gasoline each day (personal communication of the dealer). The main users of the unleaded gasoline are few Nepal Oil Corporation vehicles which are equipped with catalytic converter. It is priced NRs 38 per liter (equivalent to US $ 0.66 per liter) which is four rupees more than the cost of ordinary leaded gasoline (market price as of March, 1997).

9.2.3 Catalytic Converters

Catalytic converter (three way type) costs about 400 US $ in international market (URBAIR, 1993). A good catalytic converter can reduce upto 90 per cent of pollution caused by vehicles (URBAIR, 1993). Its life is about 168,000 km --about 6 years for the car running about 25000 km in a year --(Einsporn, 1996 in Joshi, 1996).

9.2.4 Inspection and Maintenance

His Majesty's Government of Nepal set emission standards of 65 HSU for diesel vehicles and 3 per cent carbon monoxide on gasoline vehicles in Kathmandu Valley on July 1994. In a period of first one year (1994-1995), the Valley Traffic Police (VPT) tested 13,918 vehicles, of which 7,367 met the standard after repeated attempts. Similarly in 1995-1996, a total of 6,742 vehicles had undergone emission test, of which only 3,719 passed the test. It indicates that more than 50 per cent of vehicles emitted pollutants above the limit set by the standard. None of 40 diesel 3-wheelers tested in March 1996 passed the emission test (Arya, 1996).

Green stickers are issued to the vehicles that pass emission test and red stickers for the vehicles that fail to meet the standard. Vehicles with a red sticker are denied entry to government office complex and other major areas of the city. The results of the test conducted in a period of two months (June -August 1996) provide a clear picture of emission level of vehicles in the Valley. The results are shown in Table 9.4.

Table 9.4 : Vehicle Test Results in Kathmandu (June 1996 to August 1996)

Vehicle Type	Number of Test Vehicle			Test Result		
	Gasoline	Diesel	Total	Pass	Fail	Pass (%)
Government	297	237	534	298	236	55.8
Corporation	126	113	239	131	108	54.8
Private	1.769	731	2,500	1,401	194	69.0
UN/CD	299	325	624	430	194	69.0
Hire	2.323	1,448	3.771	1,718	1,853	51.0
Tourist	41	162	203	132	71	65.0
Total	4.855	3,016	7,871	4,310	3,561	54.7

Source: Ministry of Population and Environment (1997)

The test results show that about 55 per cent of vehicles met the emission standards in the Valley in 1996. The government has also started spot checking of the vehicles that were able to get through the emission test and found surprisingly that of about 89 per cent of 3-wheelers were emitting smoke above the standards (Arya, 1996). It indicates that there could be even more vehicles which do not meet the required emission standards.

Mathur (1993) mentioned that a well run I/M program was capable of achieving a significant amount of emission reductions, of the order of 30 - 50 per cent for smoke from diesel fleet and 25 - 30 per cent for HC and CO from gasoline fueled vehicular fleet. Table 9.5 presents the effects of inspection and maintenance (I/M) on the level of smoke emission on diesel vehicles. Substantial reduction in diesel smoke was demonstrated with simple, and inexpensive maintenance measures such as changing or cleaning air filter, oil filter and adjusting injection nozzles pressure settings. The table depicts that applying I/M measures, 35 to 75 per cent reduction in smoke could be obtained. A similar type of study was also carried out by Thapathali Campus, Institute of Engineering as a part of KVVECP in 1993. The national standard of 65 HSU smoke level for diesel vehicles could be, therefore, easily achieved by almost all vehicles by providing them proper and regular maintenance.

Table 9.5: Effects of I/M Measures on Diesel Smoke in Kathmandu

Vehicle	Diesel Smoke (HSU)			I/M Measures
	Before	After	% Reduction	
Jeep (Toyota)	95	61.6	35	Air filter, fuel filter tappet
Tempo (Vikram)	94.66	45.6	51.8	Air filter, fuel filter/ tappet, injection nozzle
Truck (MBNZ)	73.33	45	38.6	Air filter/ tappet, fuel filter/tappet
Minibus (Nissan)	89.4	24	73	Fuel filter/tappet
Pick-up (Nissan)	86.16	21	75.4	Air filter, fuel filter, tappet
Land Rover	93.33	23	75.3	Air filter, fuel filter/ tappet

Source: Mathur (1993)

As in the case of smoke, the I/M measures were found to result in significant reduction of exhaust CO and HC emissions from gasoline vehicles. Proper maintenance would not only reduce emissions but also increase the fuel economy. Government regulation of 3 per cent CO level can be easily attained by all vehicles if they are maintained properly. Table 9.6 illustrates the change in CO emission if different stages of repair and maintenance are undertaken. This table also exhibits the effect on fuel economy of the proper maintenance work.

Table 9.6: Change in Emissions Level After the Servicing of Gasoline Vehicles

Vehicle	Pollu-tants	Initial *	Test 1	Test 2	Test 3	Test 4	Fuel Cons. (km/liter)		Servicing Cost
							Initial	Final	(US $)
Car	CO	19.8	4.1	3.1	2.98		8.58	17.16	62
	HC	6080	3670	4050					
Car	CO	4.13	1.6				5.75	7.05	57
	HC								
Car	CO	0.05					15	20.46	35
	HC								
Car	CO	4.59	2.3						
	HC	600	350						
Car	CO	3.14	3.1	3					
	HC	69	68						
Car	CO	4.78	4.8	3.5	3.04	2.9			9.2
	HC	2970	369	268	161	694			
Car	CO	6.98	4.5	3.9	2.7	3.1	10.7	13.3	87
	HC	2652	46		184	416			
3-wheeler	CO	5.2	5.4	1.1					
	HC	4243	6757	2237					

Source : Thapathali Campus, Institute of Engineering (1994)

Test 1: Air Filter, Battery, Exhaust Pipe, Fuel Pipeline, and Fuel Tank Leak
Test 2: Spark {lug, High Tension Cable, Ignition Timing, Centrifugal Advance Mechanism, Contact Breaker, Ignition Coil and Condenser
Test 3: Engine Oil, Oil Filter, Fuel Filter, and Thermostat
Test 4: Carburetor Idle Speed, Carburetor Float Level, Carburetor Choke Valve Linkage, Carburetor Jets and Tappet Adjustment.

(* before undergoing servicing. CO is expressed here in percentage and HC is in ppm.)

9.3 Impacts on Life-Cycle Cost

Changes in life cycle costs are calculated considering the following options;

- Use of magnetizer with and without the anticipation of fuel reduction,

- Increased vehicle maintenance,
- Use of catalytic converter and unleaded gasoline, and
- Magnetizer and increased maintenance.

9.3.1 Individual Perspective

Table 9.7 presents the life-cycle costs of different vehicles for the selected options. The table indicates that the life-cycle costs for the vehicles decrease if the use of magnetizer and fuel economy are considered. If only magnetizer was considered then there would be about 0.6 per cent to 1.5 per cent increase in life cycle cost of the vehicles. Life cycle costs of the vehicles would increase by about 9 to 20 per cent if the present expenditures on maintenance were doubled.

Table 9.7: Life-Cycle Costs With ECD/M (cents/km)

Vehicle	Initial Cost	Magnetizer		Increased O&M			CC & ULG	Magnetizer & O&M
		WOFR	WFR	2 times	3 times	4 times		
Bus	17.04	17.15	15.74	18.67	20.30	21.94	-	17.37
Minibus	14.62	14.72	13.31	15.31	16.00	16.69	-	14.00
Gasoline Car	13.85	13.95	12.60	14.75	15.65	16.55	14.45	13.50
Car (Diesel)	12.71	12.83	12.51	13.61	14.51	15.41	-	13.41
3-wheeler (D)	5.14	5.21	4.77	6.09	7.05	8.00	-	5.73
3-wheeler (P)	8.35	8.44	7.04	10.12	11.88	13.65	-	8.80
2-wheeler	4.05	4.63	4.17	4.49	4.93	5.37	-	4.61

(Note: WOFR - considering without fuel reduction, WFR - considering with fuel reduction, ULG - unleaded gasoline, CC - catalytic converter)

9.3.2 National Perspective

Table 9.8 shows the life-cycle costs of the vehicles for the selected options from the national perspective.

Table 9.8: Life-Cycle Costs With ECD/M in National Perspective (cents/km)

Vehicle	Initial Cost	Magnetizer		Increased O&M			CC & ULG	Magnetizer& O&M.
		WOFR	WFR	2 times	3 times	4 times		
Bus	13.42	13.52	12.32	14.23	15.05	15.86	-	13.13
Minibus	11.76	11.86	10.60	12.11	12.45	12.80	-	10.95
Gasoline Car	6.04	6.12	5.65	6.49	6.93	7.38	5.45	6.10
Car (Diesel)	6.7	6.80	6.53	7.15	7.60	8.04	-	6.97

3-wheeler (D)	3.79	3.86	3.48	4.27	4.75	5.22	-	3.95
3-wheeler (P)	4.09	4.17	3.63	4.97	5.85	6.72	-	4.55
2-wheeler	1.95	2.46	2.29	2.17	2.38	2.60	-	2.51

Likewise life cycle cost of the vehicles increases if magnetizer is used without considering the fuel economy resulting from its use. Life-cycle costs decreases, in-fact, from the present level if fuel economy resulting from its use is also considered. There will be 6 to 12 per cent increase in life cycle cost of the vehicles if the expenditures on repair and maintenance are doubled from the present level. Use of catalytic converters with unleaded gasoline seems more cost effective from the national perspective. The life cycle cost of using cars using unleaded gasoline and catalytic converter decrease from its present level of 6.04 cents per kilometer to 5.45 cents per kilometer. In bus and minibus, use of magnetizer along with the increased maintenance would lower their life-cycle cost from the present level, but it would slightly increase it for the other vehicles.

9.4 Emission Control

9.4.1 Emission Reduction Potential in the Valley

A test was conducted on smoke level of about 600 diesel vehicles (Rajbahak and Joshi, 1993). There were only about 2.6 per cent vehicles which met the standard set by the government. Almost all buses and tempos were emitting smoke more than 65 HSU. Likewise more than 60 per cent of vehicles had smoke level as high as 86 HSU or more. The results of the test are given in Table 9.9.

Table 9.9 : Diesel Vehicle Test Record (HSU)

Vehicle Type	up to 65	66 - 75	76 - 85	86 - 95	96 - 100	Total
Bus	0	13	51	44	0	108
Minibus	4	9	76	142	18	249
Jeep	2	6	22	42	4	76
Car	3	1	1	4	1	10
Minitruck	4	4	15	20	1	44
Truck	2	3	12	19	2	38
3-wheeler	0	1	17	28	14	60
Total	15	37	194	299	40	585
%	2.56	6.32	33.16	51.11	6.85	100

Source : Rajbahak and Joshi (1993)

According to Mathur (1993), out of 697 vehicle tested, only 6.88 per cent were found within the smoke level of 65 HSU. Mathur (1993) reporting the test results of gasoline vehicles stated that 51 per cent 4-wheelers, 77 per cent 3-wheelers and 62 per cent 2-wheelers were able to meet national standard for CO emission. There were about 35 per cent 4-wheelers, 14 per cent 3-wheelers and 23 per cent 2-wheelers found emitting CO above standard. The details of the test result are shown in Table 9.10.

Table 9.10 : Gasoline Vehicle CO Test Summary (Vehicle Population in Percentage)

Vehicle Type	CO Emission Level (%)					
	up to 3	3.1 - 4	4.1 - 6	6.1 - 8	8.1 - 10	above 10
4 wheeler	51	14	19	7	4	5
3 wheeler	77	9	8	4	1	1
2 wheeler	62	15	13	6	0	4

Source : Mathur (1993)

Vehicle fleets in Kathmandu Valley comprise more than 50 per cent 2-wheelers. The above table shows that about 40 per cent of motor cycles are emitting CO above the permissible level set for the Valley. It clearly indicates that reduction of CO in motorcycles alone can contribute significantly towards reducing total CO emission in the Valley.

9.4.2 Unleaded Gasoline and Catalytic Converter

An attempt has been made to estimate the emission reduction potential through the use of unleaded gasoline (ULG) and catalytic converter (CC) for the vehicles in the Kathmandu Valley. Lead emission will be zero from the vehicles that use unleaded gasoline. A good CC could reduce HC, CO and NOx upto 80 % compared with the similar vehicles without CC (Joshi, 1996). Equipping old vehicles with catalytic converters can cause problems specially for those places where skills for its repair and maintenance are not well developed. So it is assumed that only new cars and taxis entering the Valley in future use unleaded gasoline and catalytic converter.

Table 9.12 presents the amount of pollutants (HC, CO, NOx and Pb) expected to reduce from the use of ULG and CC based on above assumption

Table 9.12: Emission Reduction Through the Use of ULG and CC (ton)

Year	Total Emission	New Entering Cars & Taxies Use ULG and CC			
		CO	HC	NOx	Pb
2000	33875	884	119	38	1.5
2005	37536	2218	300	97	1.5
2010	41790	3839	520	169	2
2015	46811	5830	788	256	2.5
2020	52744	8706	1177	382	2.5

9.4.3 Inspection and Maintenance

Emission control through the application of control devices involves not only a high cost but also needs a lot of promotional effort because it is unknown to many users. Findings presented in Table 9.1 indicate that there is a need for an awareness program before successfully accomplishing the emission control through the control devices. In a question on how the objective of emission control can be achieved effectively, more than 80 per cent drivers mentioned pure fuel and regular servicing of the vehicles. The respondents were given five alternatives for reducing air pollution in the Valley and were asked to them to suggest the most appropriate one. The responses to the question is summarized in Table 9.13.

Almost all drivers seem to be aware on emission reducing capacity of regular and proper servicing of the vehicles. It seems to be the most desired alternative for the emission reduction from the transport sector.

Table 9.13: Respondents Perspective for Reducing Air Pollution in the Valley

		Alternatives*								
Respondents	Sample	1	2	3	4	5	6	7	8	9
Bus	10			9				1		
Jeep	16			12	1					3
Truck	15			15						
Minibus	10			10						
3-W(P)	6			6						
Taxi	35	2	1	27				1	3	1
Car	21		1	13				4	2	1
2-w	116	2	5	89	2	2	2	5	5	4
Tractor	4			4						
3-W(D)	14			14						
Total	247	4	7	199	3	2	2	11	10	9
%	100	1.6	2.9	81	1.2	1	1	4.5	4	3.6

Source: Field Survey by the author

* Alternative
1 = Strict traffic rule and government regulation,
2 = Remove polluting vehicles,
3 = Regular servicing and pure fuel,
4 = Awareness,
5 = Alternative fuel vehicles,
6 = Control devices,
7 = 1 & 3,
8 = 2 & 3,
9 = 2,3 & 4

9.5 Conclusion

ECD/M has a lot of potential to reduce vehicular emissions in the Valley. Magnetizer can reduce up to 80 per cent smoke and a significant amount of CO and HC. It also economizes the fuel consumption. Use of ULG and CC reduces the pollution level of CO, HC, NOx upto 80 per cent and Pb 100 per cent from the vehicle exhaust. The national standards set for gasoline and diesel vehicles could be maintained through a well designed and properly implemented I/M program.

Chapter 10

Issues and Policy Options

10.1 Background

The traffic and vehicular pollution problem is believed to be linked with the fact that existing transportation infrastructures, rules and regulations, existing practice and knowledge are insufficient to address those problems which arise from the growing demand for the mobility. The knowledge about the vehicular engines -- such as four stoke and two stroke, and type of fuels -- such as diesel and gasoline -- seems to be mostly lacking. People seem divided on their views on selecting the vehicles between electric and LPG. Fuel adulteration has always become a burning issue among the users. Likewise, fuel quality issues and emission standards are seen from different viewpoints. An attempt has, therefore, been made here to look into these matters related to the problem of vehicular air pollution in the Valley.

10.2 Issues of Transport Options

10.2.1 Diesel Versus Gasoline Vehicle

The concentration of the pollutants in the engine exhaust system varies with the type of engine - spark ignition (gasoline engine) or compression ignition (diesel engine). There are few vehicles which have more or less no choice on fuel. Heavy vehicles like bus, truck and minibus are mostly powered by diesel whereas 2-wheelers are designed to be powered from gasoline. There are cars which can either be powered by diesel or gasoline.

It is not possible to generalize that cars powered either by diesel or gasoline are superior to one another on emission ground. The concentration of HC in diesel exhaust is one-third to one sixteenth of that in gasoline engine exhaust effluent. Likewise concentration of CO in diesel exhaust is negligible under all operating condition except during acceleration. Concentration of NOx is also lower in diesel exhaust except during idling and deceleration (Mathur, 1993). Thus diesel engine exhaust contains much lower concentration of harmful pollutants such as HCs, CO, NOx, etc. and therefore, it is relatively less hazardous to human health.

Concentration of aldehydes and particulate matter are much higher in diesel exhaust, under all conditions of engine operation. During idling, crushing and deceleration, the quantity of particulate matter emission per cubic meter of exhaust is 25 to 50 times higher in case of diesel engine. During acceleration, it is 500 to 800 times more than that in gasoline engine exhaust (Mathur, 1993).

Cars and taxis comprise the major share on the vehicle fleet in the Valley. This will continue even in future. A survey reveals that most of cars and taxis are operating on gasoline fuel. Cars and taxis together contributed about 40 per cent on total CO emission from the transport sector in the Valley in 1996 (refer table 6.6).

In Kathmandu Valley, there is a slight variation on the price of vehicles operating on gasoline and diesel, however customs and sales tax rate are same. Due to huge price differences between gasoline and diesel fuel, diesel vehicles are, now-a-days, becoming more and more popular. If gasoline cars and taxis are replaced by diesel, then there will be a marked reduction on the emission of the CO but at the same time emission of particulate matters will increase. One of the advantages of the gasoline vehicle is that if unleaded gasoline is used alongwith catalytic converters, then it could reduce exhaust emission to a great extent -- about 80 % for CO, HCs, NOx, and 100 % for Pb. Reduction of particulate matters from diesel vehicle is expensive and such a technology is not widely disseminated in the developing countries.

Kathmandu has recently introduced the unleaded gasoline. It would help to reduce the air pollution in the Valley if the government formulates the policies that encourage the gasoline vehicle with the catalytic converter.

10.2.2 Two Versus Four Stroke Engine Vehicle

Motorcycles and scooters comprise about 55 per cent of the total vehicle fleets in the Valley. Among 2-wheelers, two-stroke vehicles are the dominant type in the Valley.

The emission level of the two and four-stroke vehicles are not same. Concentration of HCs and CO in two-stroke engine exhaust is ten and two times more than that of the four-stroke engine respectively. But the concentration of NOx in exhaust effluent of two-stroke engine is about one half to one fourth of the corresponding four-stroke engine (Mathur, 1993).

There are same rates for customs duties and sales tax for the two- and four-stroke motorcycles. The market price for the two- and four-stroke motorcycles are almost same. Lower market price encourages valley residence on their purchase of scooters in the Valley.

Kathmandu has a larger share of 2-wheelers and it is expected in the future. It means that reductions of emissions from motorcycles can have a great impacts on total emission reduction from the transport sector in the Valley. There is an immediate need for encouraging the users on selecting less polluting motorcycles between the two- and four-stroke.

10.2.3 Electric Versus LPG Vehicles

The government has provided almost the same tax privilege in terms of import duties and sales tax for the LPG run Tuk-Tuks as those are provided for electrical vehicles. Transport experts feel uneasy that Tuk-Tuks are able to get the same privilege as that of the zero emission electric vehicles. The proponents of the electric vehicles want the government to provide more tax privileges to electric vehicles than that to LPG vehicles (Sherchan, 1997). They feel that the Tuk-Tuks will be a good option from safety standpoint (TKP, Jan. 1997). To illustrate the point, they cite that Indonesia has already banned LPG run Tuk-Tuk from its vehicle fleet on the same ground.

LPG run Tuk-Tuks are operating in Bangkok since a long time. LPG cars and buses are also operating on some other countries, like Japan, Canada etc. World has more gas reserve than that of liquid fuels. Now, efforts are being made to convert liquid fuel vehicles into the gas-run vehicles for two reasons. The first is that the liquid fuel resources are shrinking from the World and the second is that gaseous fuels emit lower concentration of pollutants than that of liquid fuels. LPG run vehicles, however, are not zero emission vehicle and emit definitely more pollutants than electric vehicles. It means that electrical vehicles are preferred to the LPG vehicles in general and specially for the countries where LPG has to be imported from abroad.

At present, LPG is primarily used in residential sector in Nepal and is, hence, priced lower than its actual price[1]. There could be shortage of LPG if Tuk-Tuk starts its operation in the Valley and consequently a rise in LPG price. The government in that case may raise the price of LPG based on its actual costs. As a result, the residential users would suffer. Looking into the life-cycle costs of operation from the national perspective, LPG vehicles seem to be cheaper compared to electric vehicles.

10.3 Policy Issues

10.3.1 Present Laws and Regulations

The Motor Vehicles and Transport Management Act (2049) was amended by a government decree in 1992. It requires that all motor vehicles are subject to registration. It states clearly that the registration certificate should be issued only when the vehicles are fit for road transportation. The act obliges the government to lay down criteria based on mechanical conditions, pollution and the durability of vehicle and to issue permission accordingly. After the establishment of the Ministry of Population and Environment, a provision has been made mandatory for undergoing emission test for the 3- and 4-wheelers in the Valley. Regulation that denies the entry of polluting vehicles in government office complex and major areas in the city has led to positive impacts on emission reduction program.

Law enforcement is, however, very poor. Neither the people who are required to adhere to the provisions bother to care for law observance nor do law enforcers give thought to their duty to ensure that laws are duly executed (Rijal, 1997)

10.3.2 Fuel Quality

Quality of fuel has direct impacts on the level of emission and consequently on the quality of air. There are several measures suggested for reducing emissions through the improvement of fuel quality. These are;

- Elimination of lead content in gasoline without decreasing octane rating,
- Reducing sulfur content in diesel fuel,

[1] Upadhyaya. M. R., Nepal Oil Corporation- personal communication

- Supplying the high cetane diesel, and
- Prohibiting adulteration and contamination of fuel.

The petroleum fuels supplied by Nepal Oil Corporation (NOC) is exactly what the Indian Oil Corporation (IOC) has to offer (Giri, 1996). There is an agreement between NOC and IOC, according to which NOC purchases finished products from the international market and sells to IOC . NOC in return uplifts various required petroleum products from IOC depots located near to Nepal-India border every day (Gautam and Associates, 1994).

NOC should be able to solve the in-country problems like adulteration. Fuel adulteration appears to be an issue, though to date no comprehensive study has dealt with this issue. Consumers worry for quality of petroleum oil are reflected in many instances on the headline news of national newspapers.

Kerosene and diesel are both substantially subsidized, while gasoline is heavily priced in Nepal. The large price difference provides enough incentives for an individual to adulterate gasoline and diesel with kerosene leading to higher emissions and reduced engine life. The NOC has maintained quality control squads and has also provisions for taking action against the dealers who sell the petroleum products that cross the tolerance limit. Adulteration in petroleum products is punishable with either a three months jail sentences or a fine of NRs. 72,000 in case of gasoline and NRs. 36,000 in case of diesel, however, only a single dealer has received such a punishment till now (Giri, 1996).

As there should be proper ratio of fuel and air to facilitate the perfect combustion, adulteration prohibits perfect combustion on one hand and deteriorates the engine further resulting high emission on the other hand. The objective of the air quality improvement could, therefore, be partly achieved by supplying unadulterated oil to the consumers.

10.3.3 Emission Standards

The emission standards are 65 HSU for diesel vehicles and 3 per cent CO for gasoline vehicles. The emission control program has been able to make people aware on the emission control. However, much further efforts are still required for making the program a success. In Kathmandu Valley, motorcycles are the major polluters because of their numbers in total vehicle fleets. Regulations governing the test of emissions are limited only to 3- and 4-wheelers in the Valley. Unless emissions from the motorcycles are monitored, it may not be adequate to have significant impacts on the improvement of air quality.

Emission of HC is equally hazardous to human health. Its standard should be set with urgency and monitored alongwith that of CO and smoke.

Critics of the present emission standards say that emission standard of 3 per cent for CO are not feasible for the vehicular fleets in the Valley. Because most of the cars manufactured in India are designed for the emission level of 4 per cent CO. Bangkok has imposed emission standards for motorcycles at not more than 4.5 per cent of CO and 10,000 ppm of HC per volume of exhaust gas since January 1996 (Bangkok Post, 1996). Taiwan is, successfully, controlling motorcycles emissions by imposing a strict standard that allows no more than 2 g/km of HC and NOx and no more than 3.5 gm/liter of CO (Lachica, 1994).

Nepal has, however, set the emission standards for smoke and CO and established a system of emission monitoring at least for 3- and 4-wheelers. Properly established emission standards and effective monitoring system will have a lots of potential to reduce the existing level of vehicular emissions in the Valley.

10.3.4 I/M Program

Valley Traffic Police (VTP) has been playing a vital role on I/M program in the Valley. It is practically the only agency for implementing the entire I/M program. There is no other such organization to look after the loop holes of the program. However, it is not within the capability of an organization, like VTP, which is not specialized in pollution control, to handle such a big program.

Critics flay the emission testing program for being unable to control emissions in true sense. It is advised to make the emission testing and controlling organizations separate from each other for effective and efficient implementation of the program. It should be practical to delegate emission testing authority to private sector and the VTP could effectively control and coordinate the quality of the private testing services. Existing automobile workshops may come forward in accomplishing this task. It will be more effective if the vehicle testing is tied up with their maintenance services. Under this arrangement, the traffic police should be provided with the authority to stop vehicles on suspicion or at random to test their level of emission. Provision for a system of punishments, incentives, support measures and education to encourage compliance would be a useful complement to this approach.

10.3.5 Workshop Strengthening

There are insufficient number of well-equipped automobile workshops in the Valley. The survey work conducted by RONAST in 1993 revealed that only eight to 10 per cent workers were skilled in automobile workshop in the Valley. About 17 per cent of workshops in Valley did not have a single machine whereas 33 per cent had only one machine (Giri, 1996b). Likewise, there were 31 per cent workshops had two machines and only 19 per cent workshops having three or more machines (one machine means having a set of air compressor, second piece of machine is an addition of welding machine and the third set of additional machinery includes grinder, water pump or battery charger). There are many unregistered sub-standard workshops in the Valley (Giri, 1996b).

10.3.6 Dust Control

The high dust levels in Kathmandu make a major contribution to air pollution, both directly and indirectly. Construction plays a part in dirtying the air. Dust problem is severe in many locations where roads are just graveled and not tar sealed. In many areas even black-topped roads are not well maintained or well sealed from the sides. Unless and until, the roads are properly cleaned, there won't be a marked reduction of air pollution caused by dust. The high level of dust affects the automobiles and further contributes the increased vehicular pollution indirectly. The clogging of air and fuel filters on vehicles, which has been shown through the practical research to be the most common cause of excess emissions (Garratt, 1993).

10.4 Conclusions

Gasoline vehicles equipped with catalytic converter are better options than the diesel vehicles. Encouragement for the selection of four-stroke 2-wheeler will be able to make a significant impacts on the reduction of exhaust pollutants. Emission monitoring could be made more effective by delegating the testing task to the private companies. As the workshops in Valley are sub-standard, their quality needs to enhanced for the effective maintenance program. Kathmandu has emission standards only for smoke and CO, emission standard for HC should be established in order to improve the air quality.

Chapter 11

Conclusions and Recommendations

11.1 Conclusions

11.1.1 Transport Sector and Air Pollution

Kathmandu Valley is facing the vehicle related air pollution problems from the last decade because of the abrupt growth in vehicle number. The vehicles are expected to grow at an overall rate of 7.3 per cent per year in future.

Transport sector contributed about 31 thousands tons of pollutants in 1996. According to the vehicle forecast done for this study, vehicular pollutants are expected to reach 53 thousand tons in year 2020. There will be an overall increase in the level of emission at 2.2 per cent per year. TSPs and PM_{10} concentrations have already exceeded WHO standard in the Valley. Concentrations of carbon monoxide, sulfur dioxide and oxides of nitrogen were below the WHO standards but have reached to an alarming stage. The lead concentration in the air of the Valley was within the limit set by WHO, however road side concentration had crossed the limit.

The study revealed that CO and lead concentration would cross the WHO standard in most of the areas in the Valley by 2020. The concentrations of other pollutants (TSPs, HC, NOx, SO_2) would, however, not exceed the WHO standards for low traffic and residential areas by 2000. As concentrations of these pollutants had already crossed the WHO limit, the situation would be further worsen in heavy traffic areas.

11.1.2 Economics of Vehicle Operation and Emission

Electric vehicles, except minibus, seem to be quite expensive compared to their gasoline counterparts on existing operating condition and tax rate. LPG 3-wheelers were quite competitive to their respective diesel and electric counterparts. Diesel cars were slightly expensive than gasoline cars on its life cycle basis while seeing from the national perspective.

GHGs emission reduction can be achieved at the costs ranging from about 28 \$/ton to 600 \$/ton depending on the candidate vehicles used. Break-even gasoline prices were about two to four times higher for electric vehicles and were slightly lower for the LPG vehicles which operate on fixed route.

11.1.3 Alternative Vehicles and ECD/M

Present spare off-peak generation capacity could charge about 50 thousand electric vehicles in Nepal. Driving parameters and geo-graphical locations favor the electric vehicle in the Valley. EV can contribute to some extent on reducing emission and subsequently improving the air quality if the situation strongly favors the EVs introduction. Looking into the present development trends and likely number of future electrical vehicles, there would be about 0.57 per cent and 1.2 per cent emission reduction from the transport sector in the Valley in 2000 and 2020 respectively. This much emission reduction would be insufficient to address vehicle related air pollution problems.

About 72 per cent drivers were found to be unaware on the devices that control the emissions. However, emission mitigation through the use of ECD/M seems to be the most appropriate approach. If the ULG and CC were made mandatory for all new cars and taxis entering the Valley, then reduction of about 2 to 3 per cent emission would be successfully achieved in year 2000 and 11 to 20 per cent in year 2020. It would reduce about 884 tons of CO, 199 tons of HC, 38 tons of NOx and 1.5 tons of Pb from the transport sector in year 2000. Properly implemented maintenance program could lower smoke level to 60 HSU and CO level to three per cent for almost all vehicles. More than 80 per cent vehicle drivers thought that pure fuel and proper maintenance could reduce the exhaust emission effectively.

11.1.4 Policy and Issues

There lack the differential tax policies between the diesel and gasoline cars and also between the two- and four-stroke 2-wheelers. Gasoline vehicles equipped with catalytic converter can drastically reduce the emission. Similarly, four-stroke vehicles emit far lower pollutants compared to two-stroke.

11.2 Recommendations

The solution to the air pollution problem by vehicles has to follow a multi-pronged approach as it is a multi-dimensional problem. Looking into the major findings of the study, following recommendations are made in order to lessen the burden of ever increasing air pollution of the Valley.

11.2.1 Policy Recommendations

Awareness

There is an urgent need to generate public awareness in efforts aimed at vehicle pollution control in collaboration with government bodies, scientific and technical agencies, voluntary organization and above all the masses. The government should make the drivers aware on the alternative fuels like unleaded gasoline, and ECDs.

Fuel Quality

The fuel standard should be given high priority and controlling mechanism should be activated for checking the fuel adulteration. Fuel monitoring squad should comprise the people from consumer groups, and experts dealing on fuel quality.

Emission Standard

HC standard should be set and monitored along-with CO and smoke. Only 3- and 4-wheelers are required to undergo emission test at present. Unless motorcycles are also monitored, it may not be adequate to have significant impacts on the improvement of air quality. Therefore, 2-wheelers should also be required to pass the emission test.

I/M Program

It is suggested to make the emission testing and controlling organization separate from each other. Existing automobile workshop should be encouraged to accomplish this task.

Workshop Strengthening

It seems necessary to strengthen quality of private workshops by ensuring them with adequate skilled and manpower. There should be program for training and soft loan for improving their capabilities.

Import Policy

Second hand out-dated and mechanically defaulting vehicles should not be allowed into the Valley. The government should give import permission only to the car and taxi that are equipped with catalytic converters. There is an immediate need for encouraging the import of 4-stroke motorcycles instead of 2-stroke.

11.2.2 Recommendations for Further Study

This study envisages the following studies for the future:

- This study considers only few ECD/M options. Further work is needed to identify more attractive options. Ranking of alternative policy measures and ECD/Ms will be useful and interesting from the policy point of view.

- This study provides information more from the emission perspective. Macro economic implications of emission control options and measures are to be studied.

- Kathmandu Valley is small on its land coverage, about 20 kmeter in length and 25 kmeter in breadth. Economic and environmental implications of mass transit system need to be studied in details.

- This study has taken simpler linear "Rollback" approach in estimating the impacts on air quality. Further research is needed to develop a model for the study of ground level concentration of pollutants from mobile sources.

- Lack of air quality information for the different years make the quantitative linkage of vehicular emission with pollutants concentration impossible. There is a need to update data base of air quality in different locations.

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Annexes

Annex 4-1

Transportation Energy Survey Format
Kathmandu Valley, Nepal

Check Station: ______________ Date: ______________

1. Vehicle Type:

Bus	[ ]	Minibus	[ ]	Car	[ ]
Jeep	[ ]	3-wheeler	[ ]	Truck	[ ]
2-wheeler	[ ]	Truck	[ ]	Taxi	[ ]
Others	[ ]				

2. Ownership Type:

Commercial	[ ]
Private	[ ]
Government	[ ]
Others	[ ]

3. Type of Fuel:

Petrol [ ] Diesel [ ] Unleaded Petrol [ ]

4. Name/ Model: ____

5. Engine Size: __________ CC

6. Date of First Registration: ___________ Year ___________ Vehicle Age

7. Mileage: ______________ km/liter or _____________ Liter/km

8. Origin: _______________ Distination: _____________ Distance (km)

9. Trip per Day: ________________

10. Average Fuel Intake per Trip: ____________ Liter

11. Average Running Hours/Day: ____________ Hours

12. Average Running Days/Month: ___________ Days

13. Average Downtime Days/Month: __________ Days

14. Design Payload: ___________ Ton or ____________ Persons

15. Average Payload/Trip: __________ Ton or _________ Persons

16. Mileage Traveled Till Today: ___________ Km

17. Number of Time Milemeter Overturned : _________

18. Is your vehicle second hand ? Yes [ ] No [ ]

If Yes, what was the speedometer reading when you purchased the vehicle ? ______km

19. Average Speed: ___________ /hr or __________ Mile/hr

20. Average Fuel Consumption/Day: ________________ Liter

21. Average Fuel Consumption/Month: ______________ Liter

22. How much do you buy on an average ?

___________ Liter/week _____________ Liter/month

23. Expenditure on Fuel/ month: _____________ Rs.

24. Price of Vehicle When Purchase: ___________ Rs.

25. Present Price of Same Vehicle: _____________ Rs.

26. How frequently you visit the workshop for regular servicing ?

Each Month [ ]
Every Two [ ]
Every Three Month [ ]

27. How much do you pay per servicing on an average ? ______________ Rs.

28. How many time did you visit workshop due to breakage in last year ? _______

29. How much did you pay for the breakage last year ? ______________ Rs.

30. How much do you spend per year for regular maintenance and repair for the breakage ? ________________ Rs.

31. How much do you need to pay for tax per year?

Registration __________ Rs.
Nagar Palika __________ Rs.
Others ______________ Rs.

32. How much do you pay for insurance per year ? _______________ Rs.

33. How frequently do you replace tire ?

Each six month one tire [ ]
Each year one tire [ ]

34. How many year/month last your tire ? __________

35. How many persons are engaged in this vehicle ? __________

36. How many kilometers do you think you drive your vehicle per year ?

Less than 10.000 km [ ]
10.000 to 15.000 km [ ]
15,000 to 20.000 km [ ]
21.000 to 30.000 km [ ]
31,000 to above [ ]

37. Have you ever heard about vehicles operate on fuels other than petrol or diesel ?

Yes [ ] No [ ]

If Yes, what type of vehicle is it ? ______________________________________

38. Do you feel your vehicle emit large amount of pollutants ?

Yes [ ] No [ ]

39. Do you ever hear aabout emission control devices ?

Yea [ ] No [ ]

40. What would, in your opinion , be the appropriate measures to control vehicular emissions ?

....
....
....

Annex 5-1

Population Trend in Valley Districts and Kathmandu Valley (000)

Year	Valley Districts						Kathmandu Valley					
	Total	G.R.	Urban	G.R.	Rural	G.R.	Total	G.R.	Urban	G.R.	Rural	G.R.
1920	306.9	NA	NA		NA							
1952/54	410.9	-	196.8	-	214.2	-						
1961	459.9	0.91	218.1	0.83	241.8	0.98						
1971	618.9	3.01	249.5	1.36	369.3	4.32						
1981	766.3	2.16	363.5	3.83	402.8	0.87						
1991	1105	3.73	598.5	5.11	506.8	2.32	1075	3.83	770.4	6	304	2.32
1994							1244	4.98	917.6	6	326	2.32
2001							1763	5.1	1380	6	383	2.32
2006							2276	5.24	1846	6	429	2.32
2011							2952	5.33	2471	6	482	2.32
2021							5030	5.47	4425	6	606	2.32

Source : Shah, S.G. (1995) and CBS (1957, 1967, 1975, 1984 and 1993)

Future Population (000)

Year	Urban		Rural		Total
	G. R.	Popu.	G. R	Popu.	
1991	6	770.4	2.32	304	1075
1992	6	816.6	2.32	311	1128
1993	6	865.6	2.32	319	1184
1994	6	917.6	2.32	326	1244
1995	6	972.6	2.32	334	1306
1996	6	1031	2.32	341	1372
1997	6	1093	2.32	349	1442
1998	6	1158	2.32	357	1516
1999	6	1228	2.32	366	1594
2000	6	1302	2.32	374	1676
2001	6	1380	2.32	383	1763
2002	6	1462	2.32	392	1854
2003	6	1550	2.32	401	1951
2004	6	1643	2.32	410	2053
2005	6	1742	2.32	420	2161
2006	6	1846	2.32	429	2276
2007	6	1957	2.32	439	2396
2008	6	2075	2.32	450	2524
2009	6	2199	2.32	460	2659
2010	6	2331	2.32	471	2802
2011	6	2471	2.32	482	2952

Continue...

2012	6	2619	2.32	493	3112
2013	6	2776	2.32	504	3280
2014	6	2943	2.32	516	3459
2015	6	3119	2.32	528	3647
2016	6	3306	2.32	540	3847
2017	6	3505	2.32	553	4057
2018	6	3715	2.32	565	4281
2019	6	3938	2.32	579	4517
2020	6	4174	2.32	592	4766

(Note: G . R. = Growth Rate)

Annex 5-2

Past and Future GDP of Kathmandu Valley (1984=100)

(million NRs.)

Year	GDP Nepal	Growth Rate	GDP Kathmandu
1984	44441		5835
1985	46512	4.57	6107
1986	47427	1.69	6227
1987	50762	7.7	6665
1988	53518	4.33	7027
1989	56151	4.64	7373
1990	59151	6.37	7767
1991	62531	4.11	8210
1992	64373	3.06	8452
1993	69364	7.61	9107
	Average	6.58	
1994	73928	6.58	9707
1995	78792	6.58	10345
1996	83977	6.58	11026
1997	89503	6.58	11752
1998	95392	6.58	12525
1999	101669	6.58	13349
2000	108359	6.58	14227
2001	115489	6.58	15164
2002	123088	6.58	16161
2003	131187	6.58	17225
2004	139819	6.58	18358
2005	149019	6.58	19566
2006	158825	6.58	20854
2007	169275	6.58	22226
2008	180413	6.58	23688
2009	192285	6.58	25247
2010	204937	6.58	26908
2011	218422	6.58	28679
2012	232794	6.58	30566
2013	248112	6.58	32577
2014	264438	6.58	34721
2015	281838	6.58	37005
2016	300383	6.58	39440
2017	320148	6.58	42035
2018	341213	6.58	44801
2019	363665	6.58	47749
2020	387594	6.58	50891
2021	413098	6.58	54240

Source (for data from 1984 - 1993): CBS (1994)

Calculation of Implied Elasticity of Trip-making

Vehicle Type	Vehciel Number		GDP (Rs)		Population (000))		e
	V1	V2	Y1	Y2	P1	P2	
	1989	1996	1989	1996	1989	1996	
Bus	503	1032	7180	8036	999	1372	3.35
Minibus	979	1386	7180	8036	999	1372	0.27
3-wheeler	1684	3693	7180	8036	999	1372	4.1
Taxi	1769	3579	7180	8036	999	1372	3.4

$$e = \frac{\ln(V2/P2) - \ln(V1/P1)}{\ln(Y2) - \ln(Y1)}$$

where,

V1 = Vehicle stock at year 1989

V2 = Vehicle stock at year 1996

Y1 = Per capita GDP at year 1989

Y2 = Per capita GDP at year 1996

P1 = Population at year 1989

P2 = Population at year 1996

e = Implied elasticity of trip-making

Annex 5-4

Vehicle Forecast for Bus for Kathmandu Valley

Year	GDP million	Population "000"	GDP/Capita (NRs.)	et	Trips	et'	Vehicel Nos.
1996	11026	1372	8036	3.35	25		1032
1997	11752	1442	8150	3.35	26	3.35	1082
1998	12525	1516	8262	3.35	27	3.35	1132
1999	13349	1594	8375	3.35	28	3.35	1185
2000	14227	1676	8489	3.35	30	3.35	1240
2001	15164	1763	8601	3.35	31	3.35	1296
2002	16161	1854	8717	3.35	32	3.35	1355
2003	17225	1951	8829	3.35	34	3.35	1414
2004	18358	2053	8942	3.35	35	3.35	1476
2005	19566	2161	9054	3.35	37	3.35	1539
2006	20854	2276	9163	3.35	38	3.35	1601
2007	22226	2396	9276	3.35	40	3.35	1669
2008	23688	2524	9385	3.35	41	3.35	1735
2009	25247	2659	9495	3.35	43	3.35	1804
2010	26908	2802	9603	3.35	45	3.35	1874
2011	28679	2952	9715	3.35	46	3.35	1948
2012	30566	3112	9822	3.35	48	3.35	2021
2013	32577	3280	9932	3.35	50	3.35	2098
2014	34721	3459	10038	3.35	52	3.35	2174
2015	37005	3647	10147	3.35	54	3.35	2254
2016	39440	3847	10252	3.35	56	3.35	2333
2017	42035	4057	10361	3.35	58	3.35	2417
2018	44801	4281	10465	3.35	60	3.35	2499
2019	47749	4517	10571	3.35	62	3.35	2585
2020	50891	4766	10678	3.35	64	3.35	2674
2021	54240	5030	10783	3.35	66	3.35	2763

where,

et = Implied elasticity of trip-making taking past vehicle stock

et' = Corrected implied elasticity considering the trips

Vehicle Forecast for Minibus for Kathmandu Valley

Year	GDP million	Population "000"	GDP/Capita (NRs.)	et	Trips	et'	Vehicel Nos
1996	11026	1372	8036	0.30	33		1386
1997	11752	1442	8150	0.30	33	0.30	1392
1998	12525	1516	8262	0.30	33	0.30	1398
1999	13349	1594	8375	0.30	34	0.30	1403
2000	14227	1676	8489	0.30	34	0.30	1409
2001	15164	1763	8601	0.30	34	0.30	1415
2002	16161	1854	8717	0.30	34	0.30	1420
2003	17225	1951	8829	0.30	34	0.30	1426
2004	18358	2053	8942	0.30	34	0.30	1431
2005	19566	2161	9054	0.30	34	0.30	1436
2006	20854	2276	9163	0.30	35	0.30	1442
2007	22226	2396	9276	0.30	35	0.30	1447
2008	23688	2524	9385	0.30	35	0.30	1452
2009	25247	2659	9495	0.30	35	0.30	1457
2010	26908	2802	9603	0.30	35	0.30	1462
2011	28679	2952	9715	0.30	35	0.30	1467
2012	30566	3112	9822	0.30	35	0.30	1472
2013	32577	3280	9932	0.30	35	0.30	1477
2014	34721	3459	10038	0.30	36	0.30	1482
2015	37005	3647	10147	0.30	36	0.30	1486
2016	39440	3847	10252	0.30	36	0.30	1491
2017	42035	4057	10361	0.30	36	0.30	1496
2018	44801	4281	10465	0.30	36	0.30	1500
2019	47749	4517	10571	0.30	36	0.30	1505
2020	50891	4766	10678	0.30	36	0.30	1509
2021	54240	5030	10783	0.30	36	0.30	1514

where,

et = Implied elasticity of trip-making from past vehicle stock

et' = Corrected elasticity of trip-making considering trips

Annex 5-6

Vehicle Forecast for Taxi for Kathmandu Valley

Year	GDP million	Population "000"	GDP/Capita (NRs.)	et	Trips	et'	Vehicel Nos.
1996	11026	1372	8036	3.40	19		3579
1997	11752	1442	8150	3.40	20	3.40	3754
1998	12525	1516	8262	3.40	21	3.40	3932
1999	13349	1594	8375	3.40	22	3.40	4117
2000	14227	1676	8489	3.40	23	3.40	4311
2001	15164	1763	8601	3.40	24	3.40	4509
2002	16161	1854	8717	3.40	25	3.40	4718
2003	17225	1951	8829	3.40	26	3.40	4927
2004	18358	2053	8942	3.40	27	3.40	5146
2005	19566	2161	9054	3.40	29	3.40	5368
2006	20854	2276	9163	3.40	30	3.40	5590
2007	22226	2396	9276	3.40	31	3.40	5829
2008	23688	2524	9385	3.40	32	3.40	6065
2009	25247	2659	9495	3.40	34	3.40	6310
2010	26908	2802	9603	3.40	35	3.40	6558
2011	28679	2952	9715	3.40	36	3.40	6821
2012	30566	3112	9822	3.40	38	3.40	7080
2013	32577	3280	9932	3.40	39	3.40	7353
2014	34721	3459	10038	3.40	40	3.40	7623
2015	37005	3647	10147	3.40	42	3.40	7908
2016	39440	3847	10252	3.40	43	3.40	8191
2017	42035	4057	10361	3.40	45	3.40	8490
2018	44801	4281	10465	3.40	47	3.40	8784
2019	47749	4517	10571	3.40	48	3.40	9089
2020	50891	4766	10678	3.40	50	3.40	9406
2021	54240	5030	10783	3.40	52	3.40	9725

where,

et = Implied elasticity of trip-making from past vehicle stock

et' = Corrected implied elasticity considering trips

Annex 5-7

Vehicle Forecast for 3-wheeler for Kathmandu Valley

Year	GDP million	Population "000"	GDP/Capita(NRs.)	et	Trips	et'	Vehicel Nos.
1996	11026	1372	8036	4	46		3693
1997	11752	1442	8150	4	49	4	3911
1998	12525	1516	8262	4	52	4	4137
1999	13349	1594	8375	4	55	4	4373
2000	14227	1676	8489	4	58	4	4622
2001	15164	1763	8601	4	61	4	4879
2002	16161	1854	8717	4	65	4	5153
2003	17225	1951	8829	4	68	4	5430
2004	18358	2053	8942	4	72	4	5721
2005	19566	2161	9054	4	76	4	6021
2006	20854	2276	9163	4	79	4	6322
2007	22226	2396	9276	4	83	4	6650
2008	23688	2524	9385	4	87	4	6976
2009	25247	2659	9495	4	92	4	7317
2010	26908	2802	9603	4	96	4	7665
2011	28679	2952	9715	4	101	4	8038
2012	30566	3112	9822	4	105	4	8407
2013	32577	3280	9932	4	110	4	8800
2014	34721	3459	10038	4	115	4	9191
2015	37005	3647	10147	4	120	4	9606
2016	39440	3847	10252	4	126	4	10022
2017	42035	4057	10361	4	131	4	10466
2018	44801	4281	10465	4	137	4	10903
2019	47749	4517	10571	4	142	4	11363
2020	50891	4766	10678	4	148	4	11842
2021	54240	5030	10783	4	155	4	12328

where,

et = Implied elasticity of trip-making from vehicle past data

et' = Corrected implied elasticity considering trips

Car (Private) Forecast for Kathmandu Valley

Year	P "000"	GDP million	V	V/P (base Year)	e	GDP/P (NRs.)	I	N
1996	1372	11026	18508	0.01	2.2	8036.44	1.00	18508
1997	1442	11752		0.01	2.2	8149.79	1.01	20061
1998	1516	12525		0.01	2.2	8261.87	1.03	21734
1999	1594	13349		0.01	2.2	8374.53	1.04	23543
2000	1676	14227		0.01	2.2	8488.66	1.06	25503
2001	1763	15164		0.01	2.2	8601.25	1.07	27615
2002	1854	16161		0.01	2.2	8716.83	1.08	29906
2003	1951	17225		0.01	2.2	8828.81	1.10	32367
2004	2053	18358		0.01	2.2	8942.04	1.11	35028
2005	2161	19566		0.01	2.2	9054.14	1.13	37895
2006	2276	20854		0.01	2.2	9162.57	1.14	40971
2007	2396	22226		0.01	2.2	9276.29	1.15	44318
2008	2524	23688		0.01	2.2	9385.10	1.17	47898
2009	2659	25247		0.01	2.2	9494.92	1.18	51768
2010	2802	26908		0.01	2.2	9603.14	1.19	55930
2011	2952	28679		0.01	2.2	9715.11	1.21	60446
2012	3112	30566		0.01	2.2	9821.98	1.22	65274
2013	3280	32577		0.01	2.2	9932.01	1.24	70505
2014	3459	34721		0.01	2.2	10037.87	1.25	76107
2015	3647	37005		0.01	2.2	10146.70	1.26	82170
2016	3847	39440		0.01	2.2	10252.14	1.28	88671
2017	4057	42035		0.01	2.2	10361.10	1.29	95711
2018	4281	44801		0.01	2.2	10465.08	1.30	103239
2019	4517	47749		0.01	2.2	10570.95	1.32	111370
2020	4766	50891		0.01	2.2	10677.93	1.33	120141
2021	5030	54240		0.01	2.2	10783.30	1.34	129565

where,

P	= Population
GDP	= Gross Domestic Product
V	= Vehicle at Base Year
e	= Elasticity of the car ownership ratio to GDP
I	= Index reflecting change in the per capita income
N	= Number of vehicle

Motorcycle Forecast for Kathmandu Valley

Year	P "000"	GDP million	V	V/P (Base Year)	e	GDP/P (NRs.)	I	Ni
1996	1372	11026	57365	0.04181	2.3	8036.44	1.00	57363
1997	1442	11752		0.04181	2.3	8149.79	1.01	62264
1998	1516	12525		0.04181	2.3	8261.87	1.03	67548
1999	1594	13349		0.04181	2.3	8374.53	1.04	73271
2000	1676	14227		0.04181	2.3	8488.66	1.06	79476
2001	1763	15164		0.04181	2.3	8601.25	1.07	86174
2002	1854	16161		0.04181	2.3	8716.83	1.08	93448
2003	1951	17225		0.04181	2.3	8828.81	1.10	101266
2004	2053	18358		0.04181	2.3	8942.04	1.11	109730
2005	2161	19566		0.04181	2.3	9054.14	1.13	118860
2006	2276	20854		0.04181	2.3	9162.57	1.14	128661
2007	2396	22226		0.04181	2.3	9276.29	1.15	139342
2008	2524	23688		0.04181	2.3	9385.10	1.17	150776
2009	2659	25247		0.04181	2.3	9494.92	1.18	163148
2010	2802	26908		0.04181	2.3	9603.14	1.19	176462
2011	2952	28679		0.04181	2.3	9715.11	1.21	190932
2012	3112	30566		0.04181	2.3	9821.98	1.22	206410
2013	3280	32577		0.04181	2.3	9932.01	1.24	223199
2014	3459	34721		0.04181	2.3	10037.87	1.25	241190
2015	3647	37005		0.04181	2.3	10146.70	1.26	260685
2016	3847	39440		0.04181	2.3	10252.14	1.28	281598
2017	4057	42035		0.04181	2.3	10361.10	1.29	304279
2018	4281	44801		0.04181	2.3	10465.08	1.30	328539
2019	4517	47749		0.04181	2.3	10570.95	1.32	354770
2020	4766	50891		0.04181	2.3	10677.93	1.33	383096
2021	5030	54240		0.04181	2.3	10783.30	1.34	413552

where,

P	= Population
GDP	= Gross Domestic Product
V	= Vehicle at Base Year
e	= Elasticity of the car ownership ratio to GDP
I	= Index reflecting change in the per capita income
N	= Number of vehicle

Growth Rate of of Tourist Vehicles in Kathmandu Valley

Year	Bus		Minibus		Truck		Car/Jeep	
	Nos.	G.R.	Nos.	G. R.	Nos.	G.R.	Nos.	G.R.
1991								
1992	5		3		2		22	
1993	6	20	4	33	3	50	22	0
1994	36	500	19	375	10	233	26	18.2
1995	130	261	96	405	46	360	215	727
1996	133	2	96	0	46	0	217	0.93
	Av.	196	Av.	203	Av.	161	Av.	187

(Note: G. R. = Growth Rate in %)

Growth Rate of Government Vehicles

Year	Bus		Minibus		Truck		Tractor		Car/Jeep		3-wheeler		2-wheeler	
	Nos.	G.R.	Nos.	G. R.	Nos.	G.R.	Nos.	G.R.	Nos.	G.R.	Nos.	G.R.	Nos.	G. R.
1989	25		34		560		41		3240		137		2126	
1990	26	4.00	40	18	570	1.8	43	4.88	3324	2.59	137	0	2200	3.48
1991	28	7.69	45	13	586	2.8	45	4.65	3588	7.94	138	0.7	2290	4.09
1992	30	7.14	53	18	597	1.9	46	2.22	3749	4.49	138	0	2487	8.60
1993	30	0.00	53	0	603	1	47	2.17	3856	2.85	138	0	2622	5.43
1994	69	130.00	54	1.9	635	5.3	47	0	4217	9.36	138	0	2780	6.03
1995	72	4.35	55	1.9	681	7.2	47	0	4409	4.55	138	0	2960	6.47
1996	73	1.39	58	5.5	687	0.9	47	0	4485	1.72	138	0	2994	1.15
	Av.	22.08	Av.	8.2	Av.	3	Av.	1.99	Av.	4.79	Av.	0.1	Av.	5.04

Growth Rate of Corporation Vehicles

Year	Bus		Minibus		Truck		Tractor		Car/Jeep		3-wheeler		2-wheeler	
	Nos.	G.R.	Nos.	G. R.	Nos.	G.R.	Nos.	G.R.	Nos.	G.R.	Nos.	G.R.	Nos.	G. R.
1989	32		11		172		3		755		33		788	
1990	32	0.00	11	0	180	4.7	9	200	800	5.96	34	3	800	1.52
1991	33	3.13	11	0	193	7.2	18	100	867	8.38	35	2.9	861	7.63
1992	34	3.03	13	18	202	4.7	18	0	937	8.07	35	0	959	11.38
1993	34	0.00	13	0	209	3.5	18	0	1003	7.04	35	0	1004	4.69
1994	34	0.00	16	23	246	18	18	0	1121	11.8	35	0	1093	8.86
1995	35	2.94	18	13	275	12	18	0	1307	16.6	35	0	1208	10.52
1996	45	28.57	18	0	280	1.8	18	0	1342	2.68	35	0	1235	2.24
	Av.	5.38	Av.	7.7	Av.	7.3	Av.	42.9	Av.	8.64	Av.	0.9	Av.	6.69

Projection of Tourist Vehicles

Year	Bus	Minibus	Truck	Car/Jeep
1996	133	96	46	217
1997	150	102	51	239
1998	168	108	56	263
1999	189	114	62	289
2000	213	121	69	318
2001	240	128	76	349
2002	270	136	84	384
2003	303	144	93	423
2004	341	153	102	465
2005	384	162	113	512
2006	432	172	125	563
2007	486	182	138	619
2008	547	193	152	681
2009	615	205	168	749
2010	692	217	186	824
2011	778	230	206	906
2012	876	244	227	997
2013	985	259	251	1097
2014	1108	274	278	1207
2015	1247	290	307	1327
2016	1402	308	339	1460
2017	1578	326	374	1606
2018	1775	346	414	1766
2019	1997	367	457	1943
2020	2247	389	505	2137
2021	2527	412	558	2351

Annex 5-12

Projection of Government Vehicles

Year	Bus	Minibus	Truck	Tractor	Car/Jeep	3-wheeler	2-wheeler
1996	73	58	689	47	4485	138	2994
1997	76	63	710	48	4700	138	3145
1998	79	68	731	49	4925	138	3303
1999	82	73	753	50	5161	138	3470
2000	86	79	775	51	5408	139	3645
2001	89	86	798	52	5667	139	3828
2002	93	93	822	53	5938	139	4021
2003	97	100	847	54	6222	139	4224
2004	101	109	872	55	6520	139	4437
2005	105	117	898	56	6832	139	4661
2006	109	127	925	57	7159	139	4896
2007	114	137	952	58	7502	140	5142
2008	118	149	981	60	7861	140	5401
2009	123	161	1010	61	8238	140	5674
2010	128	174	1040	62	8632	140	5960
2011	133	188	1071	63	9046	140	6260
2012	139	203	1103	64	9479	140	6575
2013	144	220	1136	66	9933	140	6907
2014	150	238	1170	67	10408	141	7255
2015	156	257	1205	68	10906	141	7621
2016	163	278	1241	70	11429	141	8005
2017	170	301	1278	71	11976	141	8408
2018	177	326	1316	73	12549	141	8832
2019	184	352	1356	74	13150	141	9277
2020	191	381	1396	75	13780	141	9745
2021	199	412	1438	77	14439	141	10236

Annex 5-13

Projection of Corporation Vehicles

Year	Bus	Minibus	Truck	Tractor	Car/Jeep	3-wheeler	2-wheeler
1996	45	18	280	18	1342	35	1235
1997	47	19	301	0	1458	0	1318
1998	50	21	323	0	1584	0	1406
1999	53	22	346	0	1721	0	1500
2000	55	24	372	0	1870	0	1600
2001	58	26	399	0	2031	0	1707
2002	62	28	428	0	2207	0	1821
2003	65	30	459	0	2397	0	1943
2004	68	33	493	0	2604	0	2073
2005	72	35	529	0	2829	0	2212
2006	76	38	568	0	3074	0	2360
2007	80	41	610	0	3340	0	2518
2008	84	44	654	0	3628	0	2686
2009	89	47	702	0	3942	0	2866
2010	94	51	754	0	4282	0	3058
2011	99	55	809	0	4652	0	3262
2012	104	59	868	0	5054	0	3481
2013	110	63	932	0	5491	0	3713
2014	116	68	1000	0	5965	0	3962
2015	122	73	1074	0	6481	0	4227
2016	128	79	1152	0	7041	0	4510
2017	135	85	1237	0	7649	0	4811
2018	143	92	1328	0	8310	0	5133
2019	150	99	1425	0	9028	0	5477
2020	158	106	1529	0	9809	0	5843
2021	167	114	1641	0	10656	0	6234

Growth Rate of Truck in Kathmandu Valley

Year	Private		Commercial		'Total	
	Nos.	G.R	No.	G.R.	Nos.	G. R.
1989	574		986		1560	
1990	600	4.53	1000	1.42	1600	2.56
1991	851	41.83	1320	32.00	2171	35.69
1992	958	12.57	1584	20.00	2542	17.09
1993	1037	8.25	1773	11.93	2810	10.54
1994	1084	4.53	2089	17.82	3173	12.92
1995	1171	8.03	2315	10.82	3486	9.86
1996	1230	5.04	2375	2.59	3605	3.41
	Average	12.11		13.80		13.15

Growth Rate of Tractor in Kathmandu Valley

Year	Private		Commercial		'Total	
	Nos.	G.R	No.	G.R.	Nos.	G. R.
1989	337		775		1112	
1990	375	11.28	850	9.68	1225	10.16
1991	398	6.13	1154	35.76	1552	26.69
1992	405	1.76	1154	0.00	1559	0.45
1993	406	0.25	1154	0.00	1560	0.06
1994	431	6.16	1161	0.61	1592	2.05
1995	448	3.94	1161	0.00	1609	1.07
1996	448	0.00	1161	0.00	1609	0.00
	Average	4.22		6.58		5.78

(Note: G. R. = Growth Rate in %)

Forecast of Trucks and Tractors for Kathmandu Valley

Year	Trucks	Tractors
1996	3605	1609
1997	3796	1702
1998	3997	1800
1999	4209	1904
2000	4432	2015
2001	4667	2131
2002	4914	2254
2003	5175	2384
2004	5449	2522
2005	5738	2668
2006	6042	2822
2007	6362	2985
2008	6700	3158
2009	7055	3340
2010	7429	3534
2011	7822	3738
2012	8237	3954
2013	8673	4182
2014	9133	4424
2015	9617	4680
2016	10127	4950
2017	10664	5236
2018	11229	5539
2019	11824	5859
2020	12450	6198
2021	13110	6556

Annex 5-16

Number of Future Bus in Kathmandu Valley

Year	Tourist	Government	Corporation	Pri./Commercial	Total
1996	133	73	45	1032	1283
1997	150	76	47	1082	1355
1998	168	79	50	1132	1429
1999	189	82	53	1185	1509
2000	213	86	55	1240	1594
2001	240	89	58	1296	1683
2002	270	93	62	1355	1779
2003	303	97	65	1414	1879
2004	341	101	68	1476	1986
2005	384	105	72	1539	2100
2006	432	109	76	1601	2218
2007	486	114	80	1669	2348
2008	547	118	84	1735	2484
2009	615	123	89	1804	2631
2010	692	128	94	1874	2788
2011	778	133	99	1948	2958
2012	876	139	104	2021	3139
2013	985	144	110	2098	3337
2014	1108	150	116	2174	3548
2015	1247	156	122	2254	3779
2016	1402	163	128	2333	4027
2017	1578	170	135	2417	4300
2018	1775	177	143	2499	4593
2019	1997	184	150	2585	4916
2020	2247	191	158	2674	5270
2021	2527	199	167	2763	5656

Continue..

Total Number of Future Minibus in Kathmandu Valley

Year	Tourist	Government	Corporation	Pri./Commercial	Total
1996	96	58	18	1386	1558
1997	102	63	19	1392	1576
1998	108	68	21	1398	1595
1999	114	73	22	1403	1613
2000	121	79	24	1409	1634
2001	128	86	26	1415	1655
2002	136	93	28	1420	1677
2003	144	100	30	1426	1701
2004	153	109	33	1431	1725
2005	162	117	35	1436	1751
2006	172	127	38	1442	1779
2007	182	137	41	1447	1807
2008	193	149	44	1452	1838
2009	205	161	47	1457	1870
2010	217	174	51	1462	1904
2011	230	188	55	1467	1940
2012	244	203	59	1472	1978
2013	259	220	63	1477	2019
2014	274	238	68	1482	2062
2015	290	257	73	1486	2107
2016	308	278	79	1491	2156
2017	326	301	85	1496	2209
2018	346	326	92	1500	2263
2019	367	352	99	1505	2323
2020	389	381	106	1509	2385
2021	412	412	114	1514	2453

Continue..

Total Number of Future Trucks in Kathmandu Valley

Year	Tourist	Government	Corporation	Pri./Commercial	Total
1996	46	689	280	3605	4620
1997	51	710	301	3796	4857
1998	56	731	323	3997	5106
1999	62	753	346	4209	5370
2000	69	775	372	4432	5647
2001	76	798	399	4667	5940
2002	84	822	428	4914	6248
2003	93	847	459	5175	6574
2004	102	872	493	5449	6916
2005	113	898	529	5738	7278
2006	125	925	568	6042	7660
2007	138	952	610	6362	8062
2008	152	981	654	6700	8488
2009	168	1010	702	7055	8936
2010	186	1040	754	7429	9409
2011	206	1071	809	7822	9908
2012	227	1103	868	8237	10436
2013	251	1136	932	8673	10993
2014	278	1170	1000	9133	11581
2015	307	1205	1074	9617	12203
2016	339	1241	1152	10127	12859
2017	374	1278	1237	10664	13554
2018	414	1316	1328	11229	14287
2019	457	1356	1425	11824	15062
2020	505	1396	1529	12450	15881
2021	558	1438	1641	13110	16748

Continue..

Number of Future Tractors in Kathmandu Valley

Year	Tourist	Government	Corporation	Others	Total
1996		47	18	1609	1674
1997		48	0	1702	1750
1998		49	0	1800	1849
1999		50	0	1904	1954
2000		51	0	2015	2065
2001		52	0	2131	2183
2002		53	0	2254	2307
2003		54	0	2384	2438
2004		55	0	2522	2577
2005		56	0	2668	2724
2006		57	0	2822	2879
2007		58	0	2985	3044
2008		60	0	3158	3217
2009		61	0	3340	3401
2010		62	0	3534	3595
2011		63	0	3738	3801
2012		64	0	3954	4018
2013		66	0	4182	4248
2014		67	0	4424	4491
2015		68	0	4680	4748
2016		70	0	4950	5020
2017		71	0	5236	5307
2018		73	0	5539	5612
2019		74	0	5859	5933
2020		75	0	6198	6273
2021		77	0	6556	6633

Continue..

Total Number of Future Cars/Jeeps in Kathmandu Valley

Year	Tourist	Government	Corporation	Private	Commer	Total
1996	217	4485	1342	18508	3579	28131
1997	239	4700	1458	19980	3754	30130
1998	263	4925	1584	21560	3932	32263
1999	289	5161	1721	23264	4117	34551
2000	318	5408	1870	25101	4311	37007
2001	349	5667	2031	27077	4509	39633
2002	384	5938	2207	29210	4718	42457
2003	423	6222	2397	31497	4927	45466
2004	465	6520	2604	33960	5146	48696
2005	512	6832	2829	36607	5368	52148
2006	563	7159	3074	39442	5590	55828
2007	619	7502	3340	42511	5829	59801
2008	681	7861	3628	45791	6065	64027
2009	749	8238	3942	49324	6310	68563
2010	824	8632	4282	53114	6558	73410
2011	906	9046	4652	57210	6821	78635
2012	997	9479	5054	61585	7080	84195
2013	1097	9933	5491	66305	7353	90178
2014	1207	10408	5965	71354	7623	96557
2015	1327	10906	6481	76798	7908	103420
2016	1460	11429	7041	82625	8191	110745
2017	1606	11976	7649	88913	8490	118634
2018	1766	12549	8310	95628	8784	127038
2019	1943	13150	9028	102859	9089	136070
2020	2137	13780	9809	110636	9406	145768
2021	2351	14439	10656	118975	9725	156147

Continue..

Total Number of Future Three-wheeler in Kathmandu Valley

Year	Government	Corporation	Others	Total
1996	138	35	3693	3866
1997	138	0	3911	4049
1998	138	0	4137	4275
1999	138	0	4373	4511
2000	139	0	4622	4761
2001	139	0	4879	5018
2002	139	0	5153	5292
2003	139	0	5430	5569
2004	139	0	5721	5860
2005	139	0	6021	6160
2006	139	0	6322	6461
2007	140	0	6650	6790
2008	140	0	6976	7116
2009	140	0	7317	7457
2010	140	0	7665	7805
2011	140	0	8038	8178
2012	140	0	8407	8547
2013	140	0	8800	8940
2014	141	0	9191	9332
2015	141	0	9606	9747
2016	141	0	10022	10163
2017	141	0	10466	10607
2018	141	0	10903	11044
2019	141	0	11363	11504
2020	141	0	11842	11983
2021	141	0	12328	12469

Continue..

Total Number of Future Two-Wheelers in Kathmandu Nepal

Year	Government	Corporation	Private	Total
1996	2994	1235	57363	61592
1997	3145	1318	62003	66466
1998	3303	1406	66990	71699
1999	3470	1500	72371	77341
2000	3645	1600	78182	83427
2001	3828	1707	84436	89972
2002	4021	1821	91197	97040
2003	4224	1943	98450	104617
2004	4437	2073	106271	112781
2005	4661	2212	114684	121557
2006	4896	2360	123697	130952
2007	5142	2518	133472	141132
2008	5401	2686	143920	152008
2009	5674	2866	155187	163727
2010	5960	3058	167281	176298
2011	6260	3262	180370	189892
2012	6575	3481	194353	204409
2013	6907	3713	209460	220080
2014	7255	3962	225625	236842
2015	7621	4227	243074	254921
2016	8005	4510	261761	274275
2017	8408	4811	281949	295168
2018	8832	5133	303517	317482
2019	9277	5477	326762	341516
2020	9745	5843	351788	367376
2021	10236	6234	378638	395108

Annex 5-17

Number of Minibus Required Instead of 3-wheelers

Year	Required 3-wheeler	Available 3-wheeler	Short fall of 3-wheelers	Required Nos.Minibus Instead of 3-wheelers
1996	3866	3866	0	0
1997	4049	3692	357	60
1998	4275	3535	740	124
1999	4511	3385	1126	188
2000	4761	3240	1521	254
2001	5018	3103	1915	320
2002	5292	2972	2320	387
2003	5569	2845	2724	454
2004	5860	2724	3136	523
2005	6160	2608	3552	592
2006	6461	2497	3964	661
2007	6790	2391	4399	734
2008	7116	2289	4827	805
2009	7457	2192	5265	878
2010	7805	2099	5706	951
2011	8178	2010	6168	1028
2012	8547	1924	6623	1104
2013	8940	1842	7098	1183
2014	9332	1764	7568	1262
2015	9747	1689	8058	1343
2016	10163	1617	8546	1425
2017	10607	1548	9059	1510
2018	11044	1483	9561	1594
2019	11504	1420	10084	1681
2020	11983	1359	10624	1771
2021	12469	1301	11168	1862

Annex 5-18

Number of Future Vehicles with Adjustment

Year	Bus	Minibus	Truck	Tractor	Car/jeep	3-wheeler	2-wheeler
1996	1283	1558	4620	1674	28131	3866	61592
1997	1355	1636	4857	1750	30130	3692	66466
1998	1429	1719	5107	1849	32263	3535	71699
1999	1509	1801	5370	1954	34551	3385	77341
2000	1594	1888	5647	2065	37007	3240	83427
2001	1683	1975	5940	2183	39633	3103	89972
2002	1779	2064	6248	2307	42457	2972	97040
2003	1879	2155	6573	2438	45466	2845	104617
2004	1986	2248	6916	2577	48696	2724	112781
2005	2100	2343	7278	2724	52148	2608	121557
2006	2218	2440	7660	2879	55828	2497	130952
2007	2348	2541	8062	3044	59801	2391	141132
2008	2484	2643	8487	3217	64027	2289	152008
2009	2631	2748	8936	3401	68563	2192	163727
2010	2788	2855	9409	3595	73410	2099	176298
2011	2958	2968	9908	3801	78635	2010	189892
2012	3139	3082	10436	4018	84195	1924	204409
2013	3337	3202	10993	4248	90178	1842	220080
2014	3548	3324	11581	4491	96557	1764	236842
2015	3779	3450	12203	4748	103420	1689	254921
2016	4027	3581	12859	5020	110745	1617	274275
2017	4300	3719	13553	5307	118634	1548	295168
2018	4593	3857	14286	5612	127038	1483	317482
2019	4916	4004	15062	5933	136070	1420	341516
2020	5270	4156	15881	6273	145768	1359	367376
2021	5656	4315	16748	6633	156147	1301	395108

Elasticities of Vehicle Demand in Asian Countries

Country	Parameters	Year		Elasticity
		1975	1985	
Thailand	Population (million)	42.39	51.8	
	GDP (1972=100, million)	204428	394113	
	Car	281730	704647	1.57
	Motorcycle	466438	1883897	2.62
Indonesia	Population (million)	130.2	165.2	
	GDP (1983=100, billion)	45.7	80.1	
	Car	383034	987099	2.19
	Motorcycle	1191771	4765174	3.55
	Bus	33101	231463	5.2
Malaysia	Population (million)	13.128	15.725	
	GDP (1974=100, million)	1518.6	1756.4	
	Car	416229	1356731	6.88
	Motorcycle	646746	2410419	7.8
	Bus	8919	20203	4.37
	Taxi	9026	27261	6.35
Nepal	Population (million)	12.83	16.62	
	GDP (1984=100, million)	17300	24959	
	Car	10758	19979	3.34
	Motorcycle	7522	13280	2.87
	Bus	1602	4281	6.72

Source:- (REDP, 1989a, 1989c, 1989d, 1989e)

Annex 6-1

Vehicles with Route Permit in the Valley

Vehicle Type	Route	Number of Vehicle	Total
Bus	Kathmandu Valley (Shaja Yatayat)	63	
	Ratnapark - Shakhu	24	
	Ratnapark - Sundarijal	9	
	Ratnapark - Pharping	17	
	Ratnapark - Patandhoka	17	
	Ratnapark - Naya Bus Turminal	134	
			264
Minibus			
	Ratnapark - Jorpati	80	
	Ratnapark - Thankot	23	
	Ratnapark - Balaju	17	
	Ratnapark - Shankhu	8	
	Ratnapark - Kirtipur	22	
	Ratnapark - Budanilkantha	22	
	Ratnapark - Naya Thimi	18	
	Ratnapark - Lagankhel	97	
	Ratnapark - Bhaktapur	148	
	Ratnapark - Kathmandu Valley	20	
	Jorpati - Gangabu	16	
	Ratnapark - Old Thimi - Bhaktapur	38	
			509
3-wheeler meter	Kathmandu VAlley	1800	
			1800
3-wheeler without meter	Kathmandu Valley	1200	
			1200
Taxi	Kathamandu Valley	2027	
			2027

Source :- BZTMO (1997)

Annex 6-2

Number of Operating Vehicles in the Valley

Year	Bus	Op	Mini	Op	Truck	Op	Tractor	Op	Car/Jeep	Op	3-W	Op	2-W	Op
1989	560	363	1024	663	732	598	1156	711	16626	15919	1854		22359	21129
1990	663	411	1168	724	751	601	1349	790	17300	15861	2186		28407	25368
1991	718	426	1277	758	779	611	1615	901	19244	16893	3844		32240	27208
1992	792	450	1352	769	801	616	1623	862	20748	17439	3844		37774	30125
1993	847	461	1393	758	815	614	1653	836	21777	17526	3844		41663	31399
1994	1045	545	1426	744	891	658	1677	808	24354	18767	3844		49265	35086
1995	1242	620	1549	773	1002	725	1674	768	27106	20000	3852		57939	38994
1996	1283	613	1558	745	1015	720	1674	732	28131	19874	3866	3093	61594	39174
1997	1355	620	1636	749	1061	738	1750	729	30130	20382	3692	2954	66466	39947
1998	1429	626	1719	753	1109	755	1849	733	32263	20897	3535	2828	71699	40722
1999	1509	633	1801	756	1161	775	1954	738	34551	21428	3385	2708	77341	41511
2000	1594	640	1888	758	1215	795	2065	743	37007	21976	3240	2592	83427	42314
2001	1683	647	1975	760	1273	816	2183	748	39633	22535	3103	2482	89972	43124
2002	1779	655	2064	760	1334	838	2307	753	42457	23115	2972	2378	97040	43954
2003	1879	663	2155	760	1399	861	2438	758	45466	23701	2845	2276	104617	44780
2004	1986	671	2248	759	1467	885	2577	763	48696	24306	2724	2179	112781	45619
2005	2100	679	2343	757	1540	911	2724	769	52148	24923	2608	2086	121557	46464
2006	2218	687	2440	755	1618	938	2879	774	55828	25548	2497	1998	130952	47303
2007	2348	696	2541	753	1700	966	3044	779	59801	26203	2391	1913	141132	48176
2008	2484	705	2643	750	1788	995	3217	784	64027	26862	2289	1831	152008	49035
2009	2631	715	2748	747	1881	1026	3401	790	68563	27543	2192	1754	163727	49910
2010	2788	725	2855	743	1980	1058	3595	795	73410	28236	2099	1679	176298	50786
2011	2958	737	2968	739	2086	1093	3801	801	78635	28961	2010	1608	189892	51694
2012	3139	749	3082	735	2199	1129	4018	806	84195	29690	1924	1539	204409	52585
2013	3337	762	3202	731	2320	1167	4248	812	90178	30449	1842	1474	220080	53503
2014	3548	776	3324	727	2448	1207	4491	818	96557	31217	1764	1411	236842	54411
2015	3779	791	3450	722	2586	1250	4748	823	103420	32015	1689	1351	254921	55343
2016	4027	807	3581	718	2732	1294	5020	829	110745	32825	1617	1294	274275	56270
2017	4300	826	3719	714	2890	1341	5307	835	118634	33669	1548	1238	295168	57226
2018	4593	844	3857	709	3058	1391	5612	841	127038	34522	1483	1186	317482	58167
2019	4916	865	4004	705	3236	1443	5933	847	136070	35405	1420	1136	341516	59129
2020	5270	888	4156	700	3431	1499	6273	853	145768	36316	1359	1087	367376	60107
2021	5656	913	4315	696	3638	1557	6633	859	156147	37249	1301	1041	395108	61089

Vehicular Emission for the Kathmandu Valley (1996)

Fuel Type	Vehicle	Vehicle Number	Vehicle kilometer	Emmision Factor g/km						Emmision (ton)						Total
				TSPs	CO	HCs	NOx	SO2	Pb	TSPs	CO	HCs	NOx	SO2	Pb	
Diesel	Truck	720	15840	3.00	12.00	3.70	13.00	1.75		34	137	42	148	20		381
	Bus	613	45150	3.00	12.00	3.70	13.00	1.75		83	332	102	360	48		926
	Minibus	745	54335	1.50	2.25	1.26	13.00	0.39		61	91	51	526	16		745
	Jeep	4373	8740	0.90	3.10	1.30	1.40	0.38		34	118	50	54	15		271
	Tractor	732	16416	0.90	2.25	1.26	1.40	0.39		11	27	15	17	5		75
	3-wheeler	1240	31584	1.50	2.25	1.26	13.00	0.39		59	88	49	509	15		721
	Total									282	794	310	1614	119		3118
Gasoline	Car Taxi	2027	24720	0.20	62.00	8.30	2.70	0.13	0.02	10	3107	416	135	7	1	3675
	Car	15462	4800	0.20	62.00	8.30	2.70	0.13	0.02	15	4601	616	200	10	1	5444
	3-wheeler	1859	21150	0.21	22.64	14.13	0.20	0.05	0.02	8	890	556	8	2	1	1465
	2-wheeler	39174	10351	0.50	24.00	19.00	0.07	0.02	0	203	9732	7704	28	8	1	17677
	Total									236	18330	9292	372	26	4	28260
Grand Total										518	19124	9602	1986	145	4	31378

Vehicular Emission for the Kathmandu Valley (2000)

Fuel Type	Vehicle	Vehicle Number	Vehicle kilometer	Emmision Factor g/km						Emmision (ton)						Total
				TSPs	CO	HCs	NOx	SO2	Pb	TSPs	CO	HCs	NOx	SO2	Pb	
Diesel	Truck	795	15840	3.00	12.00	3.70	13.00	1.75		38	151	47	164	22		421
	Bus	640	45150	3.00	12.00	3.70	13.00	1.75		87	347	107	376	51		967
	Minibus	758	54335	1.50	2.25	1.26	13.00	0.39		62	93	52	535	16		758
	Jeep	4834	8740	0.90	3.10	1.30	1.40	0.38		38	131	55	59	16		299
	Tractor	743	16416	0.90	2.25	1.26	1.40	0.39		11	27	15	17	5		76
	3-wheeler	1037	31584	1.50	2.25	1.26	13.00	0.39		49	74	41	426	13		603
	Total									284	823	317	1577	122		3123
Gasoline	Car Taxi	2481	24720	0.20	62.00	8.30	2.70	0.13	0.02	12	3802	509	166	8	1	4499
	Car	16858	4800	0.20	62.00	8.30	2.70	0.13	0.02	16	5017	672	218	11	2	5935
	3-wheeler	1555	21150	0.21	22.64	14.13	0.20	0.05	0.02	7	745	465	7	2	1	1225
	2-wheeler	42314	10351	0.50	24.00	19.00	0.07	0.02	0	219	10512	8322	31	9	1	19093
	Total									254	20076	9967	421	29	5	30752
Grand Total										539	20898	10284	1998	151	5	33875

Vehicular Emission for Kathmandu Valley (2005)

Continue..

Fuel Type	Vehicle	Vehicle Number	Vehicle kilometer	Emmision Factor g/km						Emmision (ton)						Total
				TSPs	CO	HCs	NOx	SO2	Pb	TSPs	CO	HCs	NOx	SO2	Pb	
Diesel	Truck	911	15840	3.00	12.00	3.70	13.00	1.75		43	173	53	188	25		483
	Bus	679	45150	3.00	12.00	3.70	13.00	1.75		92	368	113	399	54		1025
	Minibus	757	54335	1.50	2.25	1.26	13.00	0.39		62	93	52	535	16		757
	Jeep	5483	8740	0.90	3.10	1.30	1.40	0.38		43	149	62	67	18		339
	Tractor	769	16416	0.90	2.25	1.26	1.40	0.39		11	28	16	18	5		78
	3-wheeler	834	31584	1.50	2.25	1.26	13.00	0.39		40	59	33	342	10		485
	Total									291	870	330	1548	128		3167
Gasoline	Car Taxi	3213	24720	0.20	62.00	8.30	2.70	0.13	0.02	16	4924	659	214	10	2	5826
	Car	18719	4800	0.20	62.00	8.30	2.70	0.13	0.02	18	5571	746	243	12	2	6591
	3-wheeler	1252	21150	0.21	22.64	14.13	0.20	0.05	0.02	6	600	374	5	1	1	986
	2-wheeler	46464	10351	0.50	24.00	19.00	0.07	0.02	0	240	11543	9138	34	10	1	20966
	Total									280	22637	10917	496	33	5	34369
Grand Total										571	23507	11247	2044	161	5	37536

Vehicular Emission for Kathmandu Valley (2010)

Fuel Type	Vehicle	Vehicle Number	Vehicle kilometer	Emmision Factor g/km						Emmision (ton)						Total
				TSPs	CO	HCs	NOx	SO2	Pb	TSPs	CO	HCs	NOx	SO2	Pb	
Diesel	Truck	1058	15840	3.00	12.00	3.70	13.00	1.75		50	201	62	218	29		561
	Bus	725	45150	3.00	12.00	3.70	13.00	1.75		98	393	121	426	57		1095
	Minibus	743	54335	1.50	2.25	1.26	13.00	0.39		61	91	51	525	16		743
	Jeep	6211	8740	0.90	3.10	1.30	1.40	0.38		49	168	71	76	21		384
	Tractor	795	16416	0.90	2.25	1.26	1.40	0.39		12	29	16	18	5		81
	3-wheeler	672	31584	1.50	2.25	1.26	13.00	0.39		32	48	27	276	8		391
	Total									301	930	348	1538	136		3254
Gasoline	Car Taxi	4160	24720	0.20	62.00	8.30	2.70	0.13	0.02	21	6376	854	278	13	2	7543
	Car	20688	4800	0.20	62.00	8.30	2.70	0.13	0.02	20	6157	824	268	13	2	7284
	3-wheeler	1007	21150	0.21	22.64	14.13	0.20	0.05	0.02	4	482	301	4	1	0	793
	2-wheeler	50786	10351	0.50	24.00	19.00	0.07	0.02	0	263	12616	9988	37	11	2	22916
	Total									308	25631	11967	587	38	6	38536
Grand Total										609	26561	12314	2125	174	6	41790

Vehicular Emission for Kathmandu Valley (2015)

Continue..

Fuel Typ	Vehicle	Vehicle Number	Vehicle kilomete	Emmision Factor g/km						Emmision (ton)						Total
				TSPs	CO	HCs	NOx	SO2	Pb	TSPs	CO	HCs	NOx	SO2	Pb	
Diesel	Truck	1250	15840	3.00	12.00	3.70	13.00	1.75		59	238	73	257	35		662
	Bus	791	45150	3.00	12.00	3.70	13.00	1.75		107	429	132	464	62		1195
	Minibus	722	54335	1.50	2.25	1.26	13.00	0.39		59	88	49	510	15		722
	Jeep	7043	8740	0.90	3.10	1.30	1.40	0.38		55	191	80	86	23		436
	Tractor	823	16416	0.90	2.25	1.26	1.40	0.39		12	30	17	19	5		84
	3-wheeler	540	31584	1.50	2.25	1.26	13.00	0.39		26	38	21	222	7		314
	Total									319	1014	373	1558	148		3412
Gasoline	Car Taxi	5385	24720	0.20	62.00	8.30	2.70	0.13	0.02	27	8253	1105	359	17	3	9764
	Car	22789	4800	0.20	62.00	8.30	2.70	0.13	0.02	22	6782	908	295	14	2	8024
	3-wheeler	811	21150	0.21	22.64	14.13	0.20	0.05	0.02	4	388	242	3	1	0	639
	2-wheeler	55343	10351	0.50	24.00	19.00	0.07	0.02	0	286	13749	10884	40	11	2	24972
	Total									339	29172	13139	698	44	7	43399
Grand Total										657	30186	13513	2257	192	7	46811

Vehicular Emission for Kathmandu Valley (2020)

Fuel Typ	Vehicle	Vehicle Number	Vehicle kilomete	Emmision Factor g/km						Emmision (ton)						Total
				TSPs	CO	HCs	NOx	SO2	Pb	TSPs	CO	HCs	NOx	SO2	Pb	
Diesel	Truck	1499	15840	3.00	12.00	3.70	13.00	1.75		71	285	88	309	42		794
	Bus	888	45150	3.00	12.00	3.70	13.00	1.75		120	481	148	521	70		1341
	Minibus	700	54335	1.50	2.25	1.26	13.00	0.39		57	86	48	494	15		700
	Jeep	7989	8740	0.90	3.10	1.30	1.40	0.38		63	216	91	98	27		494
	Tractor	853	16416	0.90	2.25	1.26	1.40	0.39		13	32	18	20	5		87
	3-wheeler	435	31584	1.50	2.25	1.26	13.00	0.39		21	31	17	179	5		253
	Total									345	1130	410	1620	164		3669
Gasoline	Car Taxi	6972	24720	0.20	62.00	8.30	2.70	0.13	0.02	34	10686	1430	465	22	3	12642
	Car	24986	4800	0.20	62.00	8.30	2.70	0.13	0.02	24	7436	995	324	16	2	8797
	3-wheeler	652	21150	0.21	22.64	14.13	0.20	0.05	0.02	3	312	195	3	1	0	514
	2-wheeler	60107	10351	0.50	24.00	19.00	0.07	0.02	0	311	14932	11821	44	12	2	27122
	Total									372	33366	14442	835	51	8	49075
Grand Total										717	34496	14852	2456	215	8	52744

Impacts on Air Quality (Considering the Highest Present Air Quality Recorded)

Year	Pollutants	PAQ	Ekt	Ekb	R	B	DAQ
2000	TSPs	775	539	518	-0.04054	10	806.0135
	CO	10	20898	19124	-0.09276	1	10.83487
	SO2	150	151	145	-0.04138	0	156.2069
	Pb	0.53	5	4	-0.25	0	0.6625
2005	TSPs	775	571	518	-0.10232	10	853.2722
	CO	10	23507	19124	-0.22919	1	12.0627
	SO2	150	161	145	-0.11034	0	166.5517
	Pb	0.53	5	4	-0.25	0	0.6625
2010	TSPs	775	609	518	-0.17568	10	909.3919
	CO	10	26561	19124	-0.38888	1	13.49995
	SO2	150	174	145	-0.2	0	180
	Pb	0.53	6	4	-0.5	0	0.795
2015	TSPs	775	657	518	-0.26834	10	980.2799
	CO	10	30186	19124	-0.57844	1	15.20592
	SO2	150	192	145	-0.32414	0	198.6207
	Pb	0.53	7	4	-0.75	0	0.9275
2020	TSPs	775	717	518	-0.38417	10	1068.89
	CO	10	34496	19124	-0.80381	1	17.23426
	SO2	150	215	145	-0.48276	0	222.4138
	Pb	0.53	8	4	-1	0	1.06

Impacts on Air Quality (Considering the Lowest Present Air Quality Recorded)

Year	Pollutants	PAQ	Ekt	Ekb	R	B	DAQ
2000	TSPs	84	539	518	-0.04054	10	87
	CO	10	20898	19124	-0.09276	1	10.83487
	SO2	13	151	145	-0.04138	0	13.53793
	Pb	0.18	5	4	-0.25	0	0.225
2005	TSPs	84	571	518	-0.10232	10	91.57143
	CO	10	23507	19124	-0.22919	1	12.0627
	SO2	13	161	145	-0.11034	0	14.43448
	Pb	0.18	5	4	-0.25	0	0.225
2010	TSPs	84	609	518	-0.17568	10	97
	CO	10	26561	19124	-0.38888	1	13.49995
	SO2	13	174	145	-0.2	0	15.6
	Pb	0.18	6	4	-0.5	0	0.27
2015	TSPs	84	657	518	-0.26834	10	103.8571
	CO	10	30186	19124	-0.57844	1	15.20592
	SO2	13	192	145	-0.32414	0	17.21379
	Pb	0.18	7	4	-0.75	0	0.315
2020	TSPs	84	717	518	-0.38417	10	112.4286
	CO	10	34496	19124	-0.80381	1	17.23426
	SO2	13	215	145	-0.48276	0	19.27586
	Pb	0.18	8	4	-1	0	0.36

Market Price and Main Features of Some Vehicles

Vehicle	Model/Make/	Main Features	Price	
			NRs.	US $
Car	Sunny/Nissan/Japan	Diesel, 2000 cc	1325000	23348
		Petrol, 1300 cc	1140000	20088
	Mazda323/Japan	Petrol, 1300 cc	1300000	22907
		Diesel, 1600 cc	1600000	28194
	Maruti 800/India	Petrol, 800 cc	620000	10925
	Maruti OMNI/India	Petrol, 800 cc	604000	10643
	Maruti 1000/India	Petrol, 1000 cc	1035000	18238
	Maruti ZEN/India	Petrol, 1000 cc		5145*
	Maruti ESTEEM/India	Petrol, 1300 cc	1260000	22203
Jeep	Maruti Gypsy/India	Petrol, 1000 cc	885000	15595
	Mahindra/India	Diesel, 2100 cc	970000	17093
Minibus	Swaraj Mazda/India	Diesel, 26 seater	1385000	24405
		Diesel, 18 seater	1530000	26960
		Diesel, 32 seater	1485000	26167
	Ashok Leyland/India	Diesel, 30 seater	1600000	28194
Tractor	Mahindra/India	Diesel, 40 HP	450000	7930
Minitruck	Ashok Leyland/India	Diesel, 4000 cc, 9 ton	1600000	28194
Motorcycle	Escourt/India	2 stroke, 100 cc	88800	15645
	Hero Honda/India	4 stroke, 100 cc	80000	1410
	Bajaj/ India	4 stroke, 100 cc	79652	1404
Sctoor	Vespa/India	2 stroke, 150 cc	66000	1163
	Bajaj/India	2 stroke, 150 cc	58000	1022

* FOB Patna

Source:- Market Survey (1997)

(Note :- 1 US $ = 56.75 NRs.)

Current Customs Duty

S.N	Items	Custom Duties	Sales Tax
1	Motor vehicles for transport of 10 or more persons. including the driver		
	a) with compression ignition IC engine (diesel)		
	- Minibuses (from 15 to 25 seats)	40	15
	- Others buses (more than 25 seats)	20	15
	- Other (up to 14 seats)	110	15
	b) Other		
	- Minibuses (from 15 to 25 seats)	40	15
	- Others buses (more than 25 seats)	20	15
	- Other (up to 14 seats)	110	15
2	Motor cars and other motor vehicles principally designed for the transports of persons (other than listed above)		
	a) With spark ignition IC engine		
	- Of a cylinder capacity not exceeding 1000 cc		
	- three-wheeler	40	15
	- others	110	15
	- Of a cylinder capacity exceeding 1000 cc but not exceeding 1500	110	15
	- Of a cylinder capacity exceeding 1500 cc but not exceeding 3000 cc	110	15
	- Of a cylinder capacity exceeding 3000 cc	110	15
3	Motor vehicles for transport of goods		
	a) With compression ignition (diesel) IC engine		
	- Gross vehicle weight not exceeding 5 tons		
	--Pick-up principally designed for the transportation of goods and accommodating 2 to 5 persons	40	15
	- - Others	20	15
	- Gross vehicle weight exceeding 5 tons but not exceeding 20 tons		

	-- Pick-up principally designed for the transportation of goods and accommodating 2 or more persons	40	15
	-- Others	20	15
	b) With spark ignition IC engine		
	- Gross vehicle weight not exceeding 5 tons	20	15
	- Gross vehicle weight exceeding 5 tons	20	15
4	Motorcycles including mopeds	40	15
5	Electric vehicles	20	0

Note:-

1. There is 50 per cent sales tax relaxed on the vehicles operating on diesel fuel and one third sales tax reduction on the vehicles operating on petrol fuel.

2. Only one per cent duty and no sales tax are levied on the import of chassis or engine fitted with chassis including parts of three-wheelers operated only with electricity, gas, or battery (i.e. Safa Tempo). Only five per cent customs duty and no sales tax are charged on engine fitted on chassis, motors, accumulators, batteries, battery chargers and other parts if imported by industry manufacturing means of transport of goods and passengers other than three-wheelers (tempo) if they are usable only in the manufacturing of those vehicles (means of transport of goods and passengers) functioning with electricity, gas, or battery (not with petrol or diesel).

3. On the recommendation of Transport Management Office only one per cent customs duty and no sales tax are imposed on imports of machines and apparatus imported by three-wheelers (or "tempo") owners with the objective of converting diesel or petrol operated three-wheelers ("tempo") into SAFA TEMPO, that is, making them operable with batteries.

Source:- 1. Department of Customs (1997)
2. Department of Value Added Tax (1997)

Life-Cycle Costs for Vehicles in the Valley (Individual Perspective)

Particulars	Diesel				Petrol			Electricity			LPG	
	Bus	Minibus	Car	3-W	Car	3-W	2-W	Trolley	Minibus	3-W(Safa)	3-W(Fixed)	3-W(Taxi)
Price ($)	24254	21856	10342	2927	8696	1716	826	75770	34537	5043	5339	4676
Government Duties ($)	7034	6338	13006	1478	11392	927	511	0	3454	50.4	54	47
Registration ($)	115	115	106	21	106	8.8	5	0	21	21	88	0
Fuel ($)	3172	3524	398	661	966	600	132	5136	947	419	892	446
O & M and Lubrication ($)	1276	878	488	457	488	391	97	1451	3804	2195	160	140
Taxes ($)	70	70	106	5	105	11	5	0	0	0	0	11
Insurance ($)	176	158	141	0	141	0	44	0	0	0	0	0
Life (Years)	20	20	25	20	25	20	20	30	30	30	20	20
Distance Covered (km/year)	45000	50000	25000	30000	25000	15000	10000	45000	50000	30000	30000	15000
Life-cycle Cost (cents/km)	17.04	14.62	12.71	5.14	13.85	8.35	4.05	28.54	15.78	10.13	5.25	6.95
Life-cycle Cost (NRs./km)	9.67	8.3	7.21	2.91	7.85	4.75	2.3	16.2	8.95	5.75	2.97	3.95
Existing Fare (NRs./km)			9		10	6.5		21		9		6.5

Life-Cycle Costs for Vehicles in the Valley in National Perspective

Particulars	Diesel				Petrol			Electricity			LPG	
	Bus	Minibus	Car	3-W	Car	3-W	2-W	Trolley	Minibus	3-W(Safa)	3-W(Fixed)	3-W(taxi)
Price ($)	24254	21856	10342	2927	8696	1716	826	75770	34537	5043	5339	4676
Government Duties ($)	0	0	0	0	0	0	0	0	0	0	0	0
Registration ($)	0	0	0	0	0	0	0	0	0	0	0	0
Fuel ($)	2718	3020	341	566	341	211	47	1540	284	126	396	198
O & M and Lubrication ($)	757	554	301	165	301	223	60	777	3178	1911	80	71
Taxes ($)	0	0	0	0	0	0	0	0	0	0	0	0
Insurance ($)	0	0	0	0	0	0	0	0	0	0	0	0
Life (Years)	20	20	25	20	25	20	20	30	30	30	20	20
Distance Covered (km/year)	45000	50000	25000	30000	25000	15000	10000	45000	50000	30000	30000	15000
At 8 % Discount Rate												
Life-cycle Cost (cents/km)	12.82	11.28	6.18	3.69	5.6	3.97	1.85	20.9	13.89	8.99	3.26	4.74
Life-cycle Cost (NRs./km)	7.28	6.40	3.51	2.09	3.18	2.25	1.05	12.04	8.00	5.18	1.85	2.69
At 10 % Discount Rate												
Life-cycle Cost (cents/km)	13.42	11.76	6.7	3.79	6.04	4.09	1.95	23.49	14.92	9.24	3.47	5.1
Life-cycle Cost (NRs./km)	7.62	6.67	3.80	2.15	3.43	2.32	1.11	13.54	8.60	5.32	1.97	2.89
At 12 % Discount Rate												
Life-cycle Cost (cents/km)	14.18	12.38	7.25	3.94	6.5	4.26	2.06	26.15	16.02	9.51	3.71	5.25
Life-cycle Cost (NRs./km)	8.05	7.03	4.11	2.24	3.69	2.42	1.17	15.07	9.23	5.48	2.11	2.98

Penetration of Electric Vehicles in Different Scenarios

Scenario I

Year	Bus	Minibus	3-W(D)	Car	Taxi	3-W(P)
1997	7	3	40	349	112	61
1998	6	4	40	349	112	61
1999	7	3	41	349	113	62
2000	7	3	41	360	145	62
2001	7	3	41	365	146	52
2002	8	4	41	370	146	52
2003	8	3	41	373	146	52
2004	8	3	41	373	146	53
2005	8	3	41	380	146	52
2006	8	4	32	385	179	57
2007	9	3	32	390	179	57
2008	9	3	32	394	180	57
2009	10	3	33	394	189	57
2010	10	4	33	400	189	57
2011	12	3	26	405	245	40
2012	12	3	25	405	245	40
2013	13	3	26	421	245	39
2014	14	4	26	421	246	39
2015	15	3	26	439	246	39
2016	16	3	21	439	318	31
2017	19	3	21	439	318	31
2018	18	4	21	441	318	32
2019	21	3	22	441	318	32
2020	23	3	22	442	318	33

Scenario II

Year	Bus	Minibus	3-W(D)	Car	Taxi	3-W(P)
1997	0	0	2	19	5	4
1998	0	0	2	19	5	4
1999	1	0	2	19	6	4
2000	1	1	2	19	6	4
2001	1	0	5	49	19	7
2002	1	0	6	49	19	7
2003	1	0	6	49	19	7
2004	1	0	6	49	19	8
2005	1	1	6	50	20	8
2006	2	0	8	100	40	13
2007	2	0	8	100	40	13
2008	2	0	9	100	40	13
2009	2	0	9	101	41	14
2010	2	1	9	101	41	14
2011	3	0	10	127	70	16
2012	4	0	10	127	70	16
2013	4	0	10	127	70	16
2014	4	0	11	128	71	16

Continued

2015	4	1	11	128	71	16
2016	6	0	12	183	112	17
2017	6	0	12	183	112	17
2018	7	0	12	185	113	17
2019	7	0	12	185	113	17
2020	7	1	12	184	114	19

Scenario III

Year	Bus	Minibus	3-W(D)	3-W(P)
1997	0	0	75	5
1998	0	0	75	6
1999	1	0	75	7
2000	1	1	75	7
2001	1	0	20	5
2002	1	0	20	5
2003	1	0	20	5
2004	1	0	20	5
2005	1	1	20	5
2006	2	0	20	5
2007	2	0	20	5
2008	2	0	20	5
2009	2	0	20	5
2010	2	1	20	5
2011	3	0	20	5
2012	4	0	20	5
2013	4	0	20	5
2014	4	0	20	5
2015	4	1	20	5
2016	6	0	20	10
2017	6	0	20	10
2018	7	0	20	10
2019	7	0	20	10
2020	7	1	20	10

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