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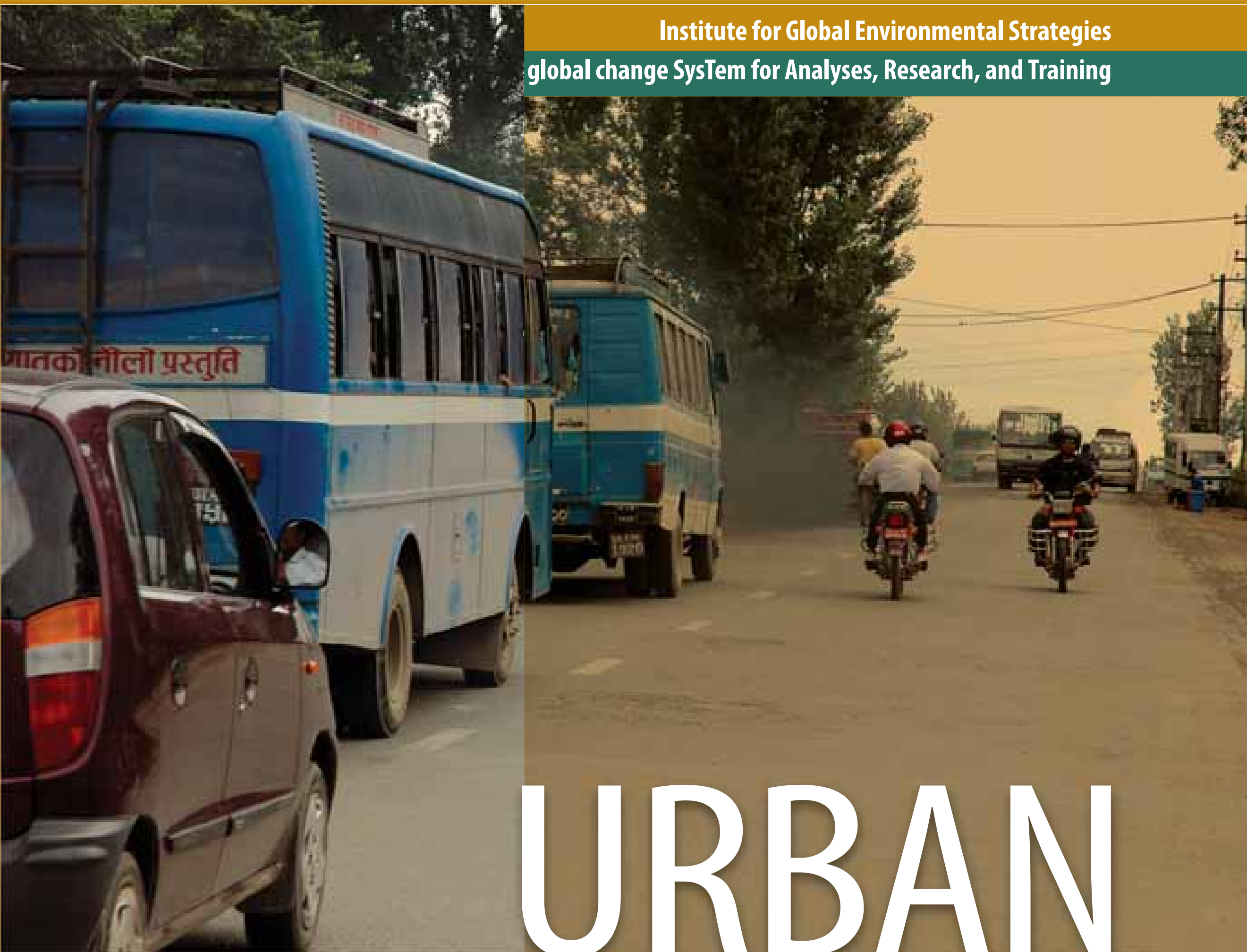

URBAN TRANSPORTATION and the ENVIRONMENT in Kathmandu Valley, Nepal

Integrating global carbon concerns into local air pollution management

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Photo: Manish Koirala

URBAN TRANSPORTATION and the ENVIRONMENT in Kathmandu Valley, Nepal

Integrating global carbon concerns into local air pollution management

By Shobhakar Dhakal

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List of abbreviations

ASIF	Activities, structure, intensity, fuel
BASE	Baseline scenario
CDM	Clean Development Mechanism
CNG	Compressed natural gas
CO	Carbon monoxide
CO_2	Carbon dioxide
DOTM	Department of Transport Management, Nepal
ELECTRIC	Scenario based on increasing the number of electric vehicles
EURO	Scenario based on gradually reducing emission standards
GHG	Greenhouse gas
HC	Hydrocarbon
IGES	Institute for Global Environmental Strategies, Japan
JICA	Japan International Cooperation Agency
LEAP	Long-range energy alternative planning
LPG	Liquid petroleum gas
MOPE	Ministry of Population and Environment, Nepal
NAAQS	National Ambient Air Quality Standards
NO_x	Nitrogen oxides
PACKAGE	Scenario based on implementing a comprehensive set of measures
PM_{10}	Particulate matters less than 10 microns in diameter
POP	Scenario based on reducing in-migration to the Kathmandu Valley
PUBLIC	Scenario based on a shift in mode from private to public transportation
SO_2	Sulfur dioxide
SPM	Suspended particulate matters
START	Global Change SysTem for Analyses, Research and Training
VOC	Volatile organic compound

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Executive summary

This study presents analyses of the current status of the emission of air pollutants and carbon dioxide (CO_2) and the energy use in the Kathmandu Valley which is associated with urban transportation. It also includes a discussion of past trends and future scenarios in order to help identify plausible synergistic mitigation measures. In this pursuit, the study developed an inventory of priority air pollutants, energy use and CO_2 emission associated with passenger transportation in the Kathmandu Valley for the past and projected these values into the future with the help of a bottom-up, dynamic accounting model and a scenario approach. In the process, a policy dialogue was held with relevant stakeholders in the Valley to identify issues of local priority (which were identified as PM_{10} emissions, congestion and energy use), past achievements, and the potential present and future avenues for policy interventions in the Valley. Using the outcomes of this dialogue, available data, and an accounting model, a number of scenarios that reflect local conditions and potential intervention avenues were formulated. These scenarios were then evaluated using a few indicators that are relevant to the local context (changes in PM_{10} emissions, number of vehicles, and conservation and utilisation of indigenous energy resources) and the global context (mitigation of CO_2 emissions).

The results of this study indicate that Kathmandu Valley's motorised travel demand increased 8.7-fold in 2004 from nearly one billion passenger-km in 1989 and suggest that it will increase to 27 billion passenger-km by 2025. Despite the drastic increase, the modal share of public and private transport modes have changed little since 1989: public transport still meets a little over 50 per cent of the demand for motorised travel. As a result, the number of vehicles operating in the Valley will triple, expanded from the 170,00 currently operating to about half a million by 2025. In the same period, the rate of ownership of cars and motorcycles is expected to double and the length of road available per vehicle to decline by one-third. The consumption of energy by passenger transportation in 2004 was seven times greater than the 658 thousand giga-joules (GJ) consumed in 1989. Projections for 2025 suggest that energy consumption will increase only about 2.2 times as more fuel-efficient vehicles penetrate the system. As is the case now, gasoline is expected to be the dominant fuel; electricity and LPG will make nominal contributions.

Private cars and motorcycles, which make up 71% of the total number of operational vehicles, currently meet just 41% of the total travel demand but consume 53% of the total energy. High-occupancy public transport vehicles like buses and minibuses comprise only 1.4% of the total number of vehicles but meet 37% of the travel demand and consume just 13% of the total energy. Using the amount of energy consumed per passenger-km on a bus as a standard unit, we find that minibuses use 20% more energy than buses, that motorcycles and microbuses use twice as much energy as buses and that private cars use 6.5 times more. It is clear that public transport is far better than private transportation from the viewpoints of reducing vehicle numbers, saving energy and meeting travel demand.

The data from six air quality monitoring stations in the Valley show that the concentrations of most of the priority pollutants are within the limits of the National Ambient Air Quality Standards (NAAQS). Concentrations of PM_{10}, however, are twice the NAAQS limits in winter months. While it is estimated that PM_{10} emissions from passenger transportation increased by 4.5 times in the five years from 1989 to 2004, emissions are expected to decrease over the next five years if emission from in-use emissions does not increase and if the current trends in other variables persist. The likely decrease in PM_{10} emission can be attributed to several factors: increased penetration of EURO-I vehicles into the fleet, expected improvements in the fuel efficiencies of new vehicles, phasing out of vehicles older than 20 years, banning of two-stroke three-wheelers and motorcycles, and slower growth in travel demand for three to four years due to the expected slowdown in economic growth. The decrease will be short-lived, however—unless there is a considerable tightening of emission standards—as the emission performance of newly introduced, EURO-I-compliant vehicles will decline and the number of vehicles will rise. As a result, the level of PM_{10} emission will catch up to and even exceed the present level by 2025. Although other priority air pollutants are within the NAAQS limits, future standards may need to be more stringent because the concentrations of CO, nitrogen oxides (NO_x), and sulfur dioxide (SO_2) are expected to increase significantly in the future.

The volume of CO_2 emission from passenger transportation in the Valley is less than it is in cities in developed regions of the world because of the low per capita vehicle ownership rates. This rate, however, has already increased 5.2 times since 1989 due to the increasing number of private cars and motorcycles and it is estimated that by 2025 it will have doubled from the 537 thousand tonnes produced in 2004. Most of the CO_2 emitted will come from burning gasoline. A person who travels by private car or motorcycle will generate over four times as many grams of CO_2 emission per km as one who travels by bus or minibus. Interestingly, the level of CO_2 emissions from microbuses is as high as that from private cars. As a result, encouraging a move from private transport to low-occupancy public transport which runs on petroleum products (gasoline, diesel or liquid petroleum gas [LPG]) will not help to reduce CO_2 emissions. Such a shift would, however, substantially reduce PM_{10} emissions.

According to our survey, past and ongoing policy initiatives and countermeasures are not comprehensive; instead, they focus mostly on controlling emissions at the tail-pipes of vehicles. This study emphasises the need for developing a comprehensive policy accompanied by a set of practical countermeasures which cover all major components of the activity-structure-intensity-fuel (ASIF) framework. It also underscores the fact that small pro-active and upstream countermeasures such as managing travel demand and promoting a modal shift towards public transportation will reduce a good deal of pressure on downstream countermeasures such as mitigating tail-pipe emissions.

Based on the baseline scenario, the study has formulated five alternative scenarios. Each incorporates a number of short- and long-term countermeasures. They focus respectively on 1) reducing travel demand by curbing in-migration, 2) promoting public transportation over private cars and motorcycles, 3) utilising electric vehicles on a large scale, 4) introducing a progressive tightening of emission standards, and 5) implementing a package of measures with small-scale interventions designed with various ASIF components in mind.

The study shows that each scenario has certain advantages but that none alone would be able to meet all five major criteria for the city: controlling PM_{10} emissions, saving energy, using more indigenous energy sources, reducing vehicle numbers to relieve congestion, and cutting CO_2 emissions. While it concludes that substantially reducing travel demand may be able to address all the objectives, it also recognises that this is a long-term measure (and one which will not have much effect in the short-term) and that failures in implementation of various urban development plans of the past call into question the likelihood of its success. It shows that increasing the share of demand met by buses and minibuses by 15% from the baseline scenario, for example, would relieve congestion but result in a 23% increase in PM_{10} in 2025. The introduction of electric vehicles on a large scale, on the other hand, would yield nominal advantages for PM_{10} and CO_2 reduction but would have no impact on congestion. For its part, implementing progressively more stringent emission standards-up to EURO-III in 2015—would not help reduce congestion or save energy and would not utilise more electricity. Some of the core messages from the analyses of the five scenarios follow:

- Implementing EURO-II norms from 2010 can significantly reduce emissions over the current EURO-I norms, but the implementation of EURO-III for new vehicles in 2015 would have nominal benefits by 2025.
- Tightening emission standards is very effective in reducing SO_2, PM_{10} and NO_x. It is, therefore, a necessary but insufficient step.
- The introduction of a large-scale bus system as a means to improve public transportation will considerably reduce the number of cars, motorcycles, and low-occupancy public transport vehicles and thereby reduce congestion and energy usage.

In sum, a package of counter-measures designed to bring about small-scale improvements in each component of the ASIF framework is the best way to address the multiple objectives of the city. Such a package would, by itself, embrace all of the objectives each scenario independently addresses. Another likely advantage of introducing incremental interventions in multiple sectors is less complexity in terms of management and political feasibility of implementation than to doing too much in only one sector. This balanced package can reduce CO_2 emissions by 20%, PM_{10} emissions by 47%, the number of cars and motorcycles by 132,824, and energy use by 18%. Electricity usage will rise by 8 million KWH from the baseline case in 2025 alone.

This study shows that there is a strong synergy between local and global objectives in the Kathmandu Valley. For specific countermeasures, priorities may differ and conflicts may arise, but to meet the overall objectives of the city outlined at the policy dialogue–controlling PM_{10} emissions, saving oil, using more electricity, mitigating congestion and reducing CO_2 emissions–the best choice is to adopt this set of policy measures, whether CO_2, the global objective, is considered or not. Because of this synergy, the Kathmandu Valley can benefit from climate policy-motivated international financial mechanisms such as Clean Development Mechanisms (CDMs) and from other mechanisms introduced by bilateral and multilateral institutions.

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About this study

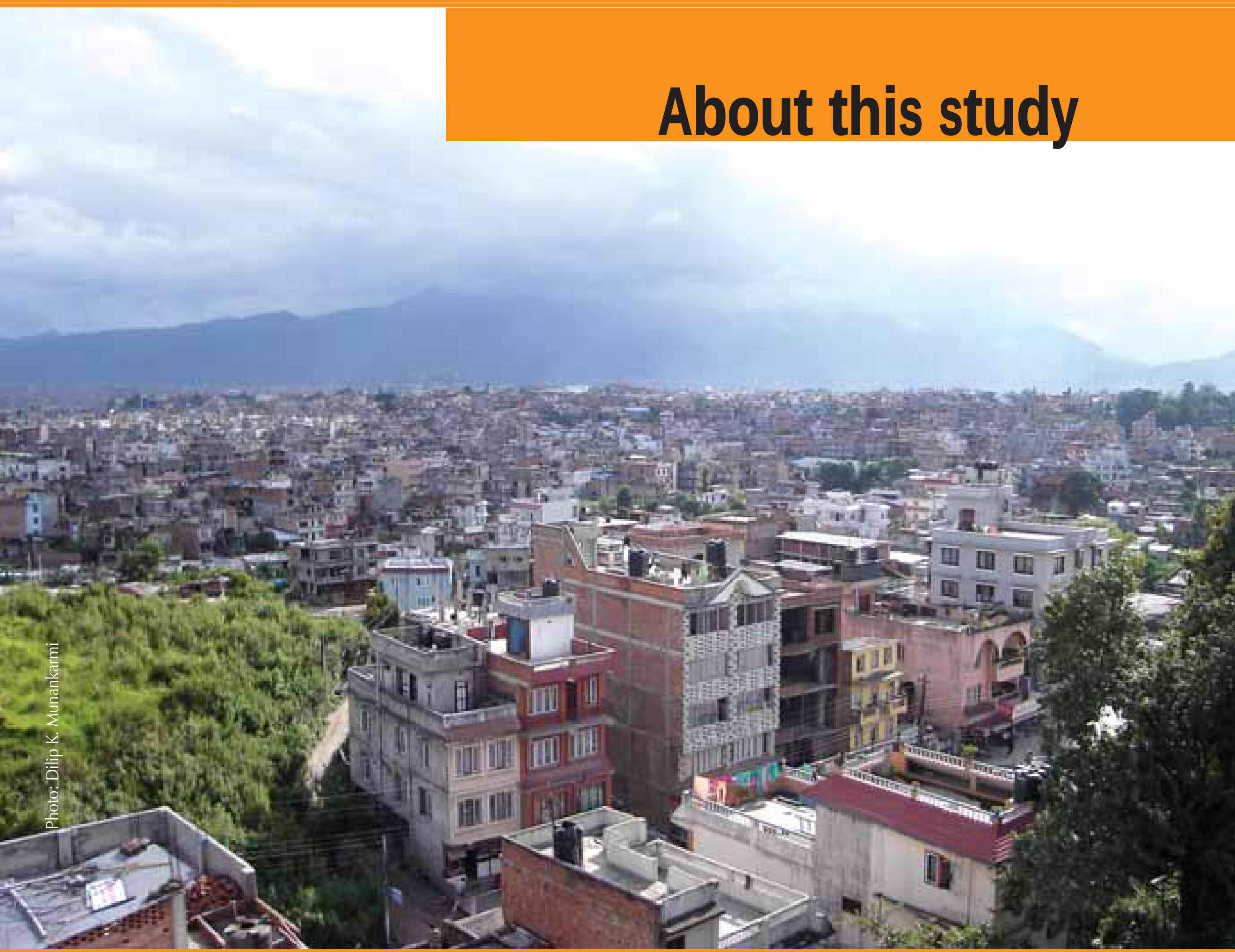

Photo: Dilip K. Munankarmi

1.1 Global context

The global environmental consequences of anthropogenic greenhouse gas (GHG) emissions are an urgent concern in the scientific community. The United Nations Framework Convention on Climate Change (UNFCCC), which was adopted in May 1992, sets an ultimate objective of stabilising GHG concentrations in the atmosphere at a level that will prevent dangerous human-induced interference with the climate system. The Third Assessment Report of the Inter-governmental Panel on Climate Change (IPCC) states clearly that the factor primarily responsible for climatic changes is the emission of anthropogenic GHGs. Cities, especially rapidly growing ones, can play a vital role in mitigating the emission of anthropogenic GHGs, both directly[1] and indirectly.[2] The nature of urban transportation in the cities of developing countries is crucial due to rapid growth in motorisation and the consequent upsurges in levels of local air pollution and carbon dioxide (CO_2) emissions. Though not all local measures will reduce CO_2 emissions, there are many opportunities for cities to consider global environmental considerations in their local air pollution management practices. Regardless of the idiosyncratic attributes of any given city—its size, income, or scale of emissions—it must create a synergy between local and global interventions.

In a recently published report entitled “Mobility 2030: Meeting the Challenges to Sustainability,” the World Business Council for Sustainable Development (WBCSD) estimates that worldwide transport-related GHG emissions (from well to wheel and including air, water and road transportation) will increase from slightly over six giga-tonnes (Gt) of CO_2 in the year 2000 to over 14 Gt by the year 2050 (WBCSD, 2004). Light-duty vehicles are responsible for the majority of emissions, while freight trucks and air transportation are the second and third greatest emitters respectively

1. Direct emissions.
2. Emissions embedded in materials and service.

(pp 37). The International Energy Agency estimates that globally road transport accounts for the majority of CO_2 emissions from the transport sector and that road transport alone generated 18% of the world's CO_2 emissions from fuel combustion in the year 2000 (IEA, 2002). In the case of OECD countries, this share stands at 23%. The WBCSD projections indicate that CO_2 emissions from each transport mode and from every region around the world will increase but that the majority of the additional growth will come from developing regions. In particular, the 18% and 29% declines in energy consumption through improved energy efficiency in light-duty vehicles and heavy-duty trucks respectively between 2000 and 2050,[3] which is the only factor slated to reduce emissions, will not offset the projected 123% and 241% rates of growth in the transport activities of these types of vehicles. China and India together surpass the transport-related emissions from all other Asian countries due to their size and to their rapid rates of motorisation; this was the case in the year 2000 and will again be the case in 2050. Although the WBCSD report does not pay enough attention to non-technological aspects of mobility issues and issues such as the role of public transportation (railways, non-motorised modes, buses, rapid transit and other measures) vis-à-vis private transportation, it does bring several major issues to the forefront: the need to cope with growing motorisation, find solutions to increasing CO_2 emissions which take into account air pollution mitigation, promote energy saving, and mitigate congestion in dense and growing Asian metropolises.

Asian cities, unlike North American and European cities, tend to be denser at the centre and to sprawl at the periphery. Sprawling leads to the creation of largely unorganised peri-urban areas that over-stretch the distribution and transport systems of the city. The emergence of peri-urban areas outside of Bangkok and the construction of fourteen satellite towns outside Beijing's fifth ring road, for example, may place additional burdens on both cities if urban functions are not well allocated. The densification of cities is desirable because it promotes a high utilisation rate of urban infrastructures, increases the cost effectiveness of public transportation, and results in compact distribution and supply networks of energy and other services. As a city becomes denser, however, it becomes more challenging to manage concerns like air pollution from motor vehicles,

3. The global average; values differ from region to region.

congestion, and urban environmental services such as water, wastewater and solid waste management. Recent estimates by the UN Population Division show that about half of the mega cities (cities with populations over ten million) and medium-size cities (cities with populations over one million) worldwide will be in Asia by 2015 (UN, 2002). Although CO_2 emissions are significantly less from Asian countries than from OECD countries, Asian countries are urbanising rapidly and their cities are quickly becoming economically developed. If we consider Asian giants such as China and India, it becomes clear that the current trends of motorisation alone will pose a serious challenge. To make mobility sustainable in the future requires balancing private, public and mass transportation and taking into account air pollution, energy saving, congestion, and CO_2 emissions. Although safety, equity, financial stability and other issues also play a role in the debate, this author believes that congestion, CO_2 emissions and the development of public transportation (and, in particular, mass transportation) will be the most serious challenges in the next 20 to 30 years. The WBCSD study supports this position. Its modeling shows that transport-related conventional emissions will decline sharply in OECD countries over the next two decades and that in non-OECD countries levels of lead, CO and volatile organic compounds (VOCs) will gradually decrease but that levels of NO_x and PM_{10} may not start declining for another two decades.

1.2 Past research

The nature of the transportation-energy-emission complex in the cities of many developing countries, especially those in South Asia, is poorly understood. A number of studies have been carried out in cities, but they focus merely on tail-pipe emissions. The actual relationship, however, is far more complex. Such a limited consideration often results in unwanted consequences, or a “rebound effect”[4]. What is lacking is a comprehensive and integrated analysis (and a strategic ap-

4. The “rebound effect” refers to unaccounted for negative implications (or feedback loops). For example, road construction and widening decreases congestion but may increase the number of vehicles and their usage on roads. In practice, gains made from supply side management often increase the scale of the problem rather than solving it.

proach) involving the interaction of urbanisation, transportation, energy, and emissions (local air pollution and carbon). The lacuna exists even in the case of well-studied Asian cities such as New Delhi and Beijing and other cities outside Asia. The shortcoming is primarily due to the differences between and the limitations of the sector-specific approach of urban planners, transportation engineers and energy-environment experts. The existing literature points to two clear trends in the nature of studies on the factors driving energy and emissions. Urban planning, land-use and core transportation studies analyse emissions solely as a function of travel demand and automobile dependency; they usually limit their recommendations to appropriate ways to reduce travel demand and automobile dependency. The studies of energy planners, in contrast, start from the perspective of a technological fix, fuel substitution and fuel quality. These two approaches are seldom integrated. This study will attempt to remedy that deficiency by pursuing an integrated approach.

1.3 Local context

Kathmandu Valley suffers from serious air pollution (Shrestha and Malla, 1996; Shah and Nagpal, 1997; Dhakal, 1996; Devkota, 1993; LEADERS, 1999). Piecing together a number of past studies yields an outline of the major problems the Valley faces:

- Growing congestion and supply-side problems
- Chaotic public transportation
- Serious air pollution
- Rapid growth in the number of private cars and motorcycles
- Two- and three-wheelers with two-stroke engines
- Aging vehicles
- Weak institutional capacity and arrangement; widespread institutional failure
- Weak enforcement of emission standards and inspection and maintenance (I&M) systems for in-use vehicles
- Low-quality fuels and widespread fuel adulteration

The concentrations of pollutants, mainly particulate matters, in the Valley exceed WHO guidelines[5] by several times. Measurements show that the 24-hour average PM_{10}

5. 70 mg/m³ and 120 mg/m³ are the 24-hour averages for PM_{10} and TSP respectively.

concentrations are 225, 135 and 126 mg/m^3 and that TSP concentrations are 376, 214 and 137 mg/m^3 respectively in the core, sub-core and remote parts of the city (NESS, 1999). Since Kathmandu is surrounded by mountains, topographic condi-tions exacerbate the pollutant concentrations and accelerate the photochemical reaction rates responsible for smog formation and visibility loss. Visibility has decreased significantly from 1970 to 1993 (Shrestha, 1995). Kathmandu Valley residents are exposed to high concentrations of PM_{10} in their daily lives and their health and welfare is seriously threatened by pollutants. Studies report that the transportation sector is the major contributor (Shrestha and Malla, 1996; Shah and Nagpal, 1997). Only a few studies consider the implications of different options for meeting the energy demands and controlling the environmental emissions of the transportation sector of the Valley. The most important ones are Dhakal (2003a), Shrestha and Malla (1996), Pradhan (1994) and Adhikari (1997). Dhakal (2003a) focuses on passenger transportation, while Shrestha and Malla (1996) inventory pollutants rather than pose options. There is a clear need for studies which explain the holistic interaction between urbanisation, transportation and emissions. Although the scale of CO_2 emissions from Kathmandu Valley is not likely to be large, studies of the synergies and conflicts between local pollution management and a carbon-friendly development path ought to be carried out.

1.4 Goals, research questions and objectives

The goal of this study is to contribute towards reducing local air pollution and GHG emissions by producing scientifically sound analyses of various options of practical policy significance in the Kathmandu Valley. To do so, this research project has created a better understanding of the interactions among urbanisation, transportation, energy and emissions and provided plausible strategies for overcoming the problems detected.

The study addresses the following specific questions:

- Among the various factors which govern air pollution and CO_2 emissions from transportation, which are the most important?

- What strategies can reduce energy use, air pollution and CO_2 emissions?
- What are the implications of these strategies for energy use, air pollution and CO_2 emissions? What barriers might impede the implementation of such strategies?

The objectives of this project were defined as follows:

- Create an up-to-date and time series quantitative database of various factors governing energy use and emissions from transportation
- Collect up-to-date qualitative information related to transportation, energy use and emissions, such as information pertaining to institutional, technological, financial, geographic, socio-cultural, and regulatory (standards, rules and regulations) sectors to use for framing possible strategies
- Develop a simple, bottom-up systems model for energy use and emissions
- Quantify the implications of various scenarios formulated using different strategies

This study considers only passenger transportation and excludes trucks and tankers. It was carried out in conjunction with a series of other studies that the principal investigator is involved in at the Institute for Global Environmental Strategies (IGES).

chapter TWO

Asian urban transport and environment issues

Regional perspectives

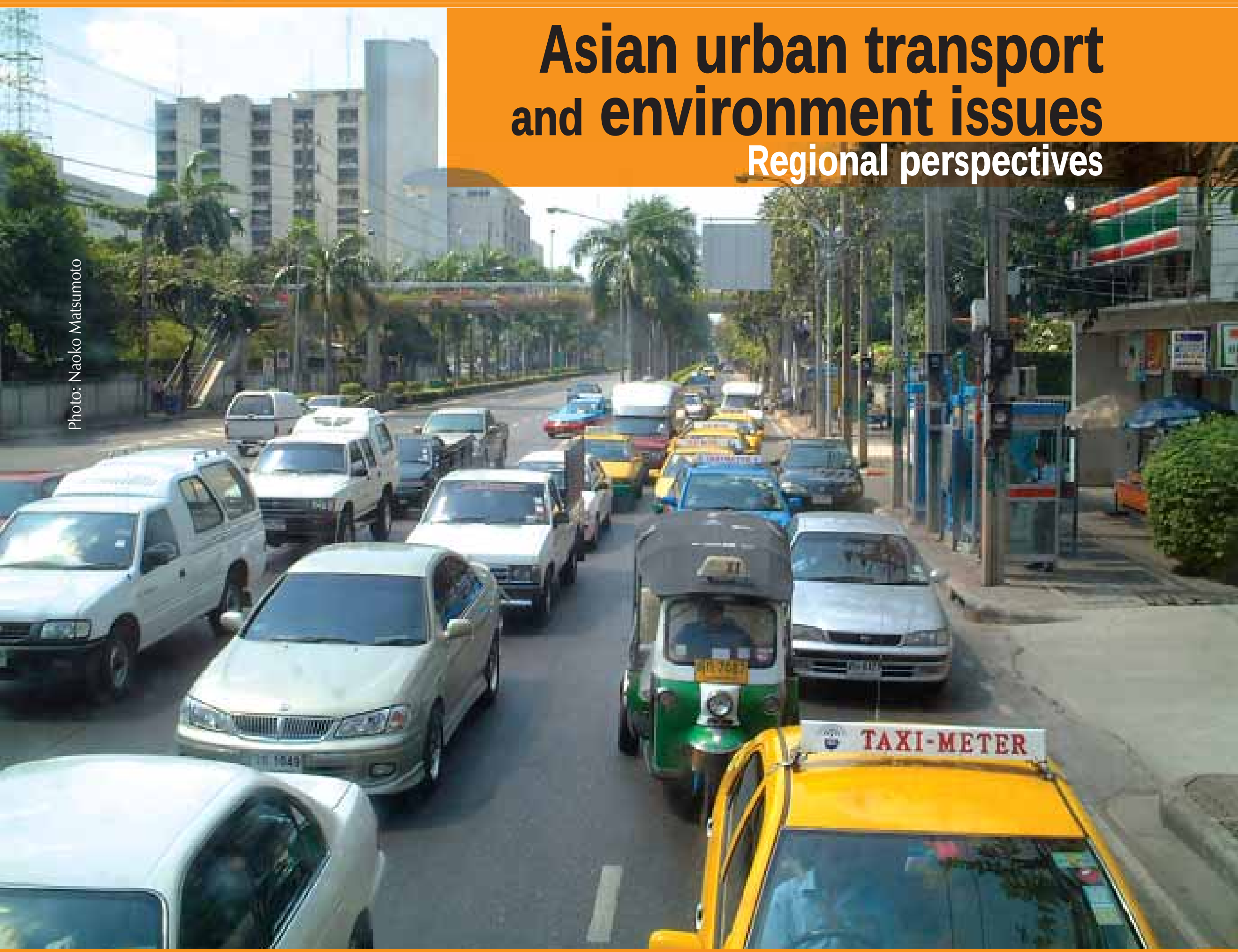

Photo: Naoko Matsumoto

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The impacts of urban transport on air pollution in Asian cities are significant and have been gradually increasing over the last few decades (ADB, 2003). In Japanese cities such as Kitakyushu, Kawasaki, Osaka, and Tokyo, the levels of traditional air pollution produced by industries—sulfur oxides, smoke and dust—have dramatically declined in the last four decades; urban transport-related air pollution, such as NO_x and SPM, however, is posing an increasingly serious challenge to policy makers. Rapidly industrialising cities in North Asia such as Beijing, Shanghai and South East Asian cities such as Ho Chi Minh (Hanoi), Bangkok, Jakarta and Manila exhibit a similar trend. On the one hand, industry-related air pollutants are decreasing, but, on the other hand, transport-related pollutants are becoming increasingly difficult to control (IGES, 2004). Due to rapid motorisation and little competition for private modes, time-space compression is being experienced: issues that evolved gradually over forty years in developed cities are now taking place in ten in rapidly industrialising cities. The result is that managing air pollution has become a greater burden than it ever was.[6] In big cities, industries are slowly but steadily being relocated to the peripheries of cities or even outside city boundaries. One study demonstrates that the consistent rise in the tertiary sector and fall in the primary industry in 22 East Asian cities (Dhakal and Kaneko, 2002), has made cities slowly become more commercial. As this change occurs, urban mobility, rather than levels of industrialisation, gradually has become the primary determinant of urban air pollution.

Epidemiological studies show that air pollution results in thousands of deaths and a number of health problems in cities. It also increases medical costs and decreases productivity. The following pollutants released by urban transport pose a threat to health: lead, dust (due to resuspension), PM, NO_x, and VOCs.[7] The photochemical oxidant ozone, which is formed by NO_x and VOCs

6. For more discussion of the "telescopic time-space compression" of urban environmental issues, see Marcotullio and Lee (2003).
7. Other pollutants, such as carcinogenic poly-nuclear aromatic hydrocarbons (PAHs) and aldehydes are also present.

in the presence of heat and sunlight, is another significant pollutant. Of course, transport is only one of many contributors to urban air pollution, but as household cooking switches to modern fuels (gas, LPG, and electricity); as low-quality industrial fuels like lignite or low-grade coals and dirty heavy diesel are replaced by cleaner coals, oils and natural gas; and as industries are moved out of cities, the contribution of transport rises dramatically. Stationary sources are easy to spot and regulate, especially as they often cause annoyance to the polluters themselves. Mobile sources, in contrast, are harder to spot and regulate, and rarely disturb polluters directly.

The impacts of these pollutants are highly location-specific. Before leaded gasoline was phased out, lead was a major health threat. Studies estimate that in Bangkok there were 400 additional deaths per year due to the effects of lead (Michaelowa, 1997). Recently, respirable PM and ozone have become increasingly more serious pollutants in Asian cities and urban transport is becoming more responsible for creating them. World Bank's UrbAir study conducted in Greater Mumbai, Kathmandu Valley, Jakarta and Metro Manila shows that urban transport accounts for the majority of air pollutants and that its health impact runs into millions of dollars (Shah and Nagpal, 1997). Another study conducted by the World Bank in Mumbai, Shanghai, Manila, Bangkok, Krakow and Santiago indicates that the total social cost of air pollution in these cities was as high as 2.6 billion 1993 US$ (Lvovsky *et al.*, 2000). A 1998 study of Delhi suggested that 7,500 premature deaths, four million hospital admissions and 242 million incidences of minor sickness could be avoided if air pollution conformed to the WHO-suggested levels in areas where the transport sector accounts for over 70% of air pollution (Xie *et al.*, 1998). A recent report by the Asian Development Bank (ADB) shows that SPM and PM_{10} levels in Asian cities are higher than WHO and U.S. EPA 1997 limits respectively (1990-1999 average, citing WHO's Air Information Management Database). In particular, SPM concentrations in Shanghai, New Delhi, Mumbai, Guangzhou, Chongquin, Calcutta, Beijing and Bangkok exceed WHO limits (90 $\mu g/m^3$) by between two and five times (ADB, 2003). PM_{10} exceeds the US EPA limit (50 $\mu g/m^3$) by several times in a number of cities; New Delhi and Calcutta, for example, have four times the limit. Similarly, a benchmark report of the Air Pollution in Mega-Cities of Asia

Project shows that NO_x and PM are a serious challenge for Asian cities (APMA, 2002). Data from Tokyo shows that SPM increased rapidly from 40 $\mu g/m^3$ in the early 1980s to over 70 $\mu g/m^3$ in the early 1990s. Since then, levels of SPM have decreased or stagnated but it is again becoming increasingly difficult to contain them (TMG, 2004). It is important to note that the health impacts of air pollution are determined by the concentrations of pollutants that populations are exposed to. All these reports indicate that SPM, PM_{10} and NO_x are particularly problematic and that the transport sector is a major contributor to their creation.

In addition to its impact on local air pollution, growing motorisation results in a significant toll on congestion, too. Incomes in cities are rising rapidly and improvements in the efficiency of public transportation, especially mass transportation, have been slow. As a result, Asian cities such as Bangkok, Jakarta, Beijing, Manila, Delhi and Kathmandu are dominated by personal, low-occupancy vehicles, whose numbers exacerbate congestion and pollutant concentrations. The expansion and improvement of roads only serves to encourage increased vehicle numbers and use. Policy makers must not only mitigate air pollution but also reduce congestion.

Many urban transport issues concern energy use. Because so much of world politics revolves around oil supplies, rapid motorisation poses an energy security concern. The consensus is that oil will continue to be a major transportation fuel and that the world has to deal with the environmental implications of oil-based transport for at least three to four more decades. There little disagreement that hydrogen-based fuel cell vehicles will evolve in the future, but major questions, like how long it will take and how hydrogen will be obtained, remain. The fuel cell system will be more efficient than the internal combustion engine but cost, energy loss and GHG emissions will determine its real benefits. Some researchers argue that even if a hydrogen-driven fuel cell automobile became cost effective today (and the technology is just being developed), it would still take over fifty years to clean our air if we accounted for the time required for designing, technology refinement, cost reduction through economies of scale, developing supporting infrastructure, marketing, and penetrating the existing fleet.[8] Heywood and Bandivadekar (2003)

8. Personal communications with John Heywood, Professor of Automotive Science, Massachusetts Institute of Technology, Cambridge, during an OECD Ministerial Roundtable on Sustainable Mobility, September 2004.

show that the new technology must penetrate over 35% of new vehicle production and over 35% of the total mileage driven to have an impact. In addition, it will take more time for fuel cells to penetrate developing Asian countries than they do to penetrate the developed economies of Asia, North America, and Europe. The latest figure indicates that oil accounts for more than 95% of total energy use in transportation in almost all OECD countries (Fulton, 2001) and that Asian cities are no different. Energy use by oil-based urban transport has increased dramatically in Asian cities owing to rapid motorisation. In rapidly growing mega cities such as Beijing and Shanghai the share of urban transport in total energy consumption is low—just 7 to 9%—but its rate of growth is over 11% (IGES, 2004). In Ho Chi Minh City, the share is greater—20%—and in commerce-dominated cites such as Tokyo and Seoul, it is well over 35%. The share and the growth of the transport sector in energy use have been phenomenal in other Asian cities too. Energy use by transport increased by over two times in Beijing, Shanghai and Delhi between 1990 and 2000. Even in relatively mature cities it climbed—by 25% in Tokyo and by 50% in Seoul, for example.

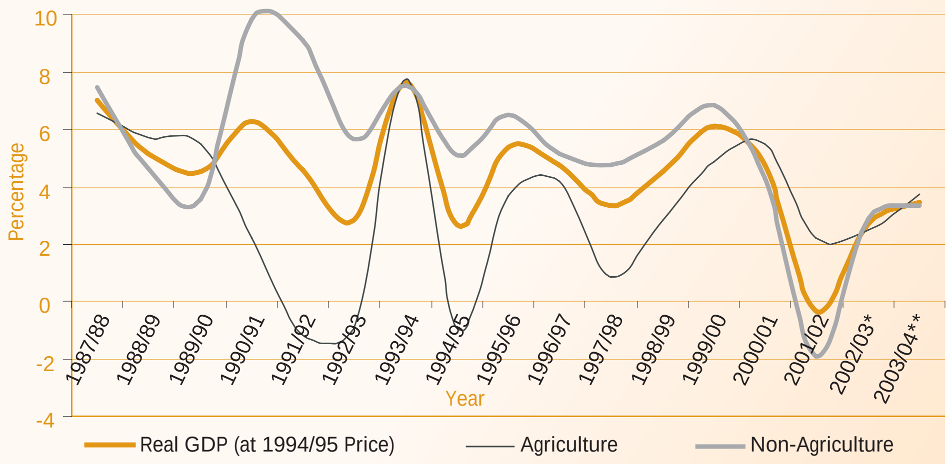
Since the Rio Earth Summit was held in 1992, the issue of climate change has been gaining attention in political, scientific and all other policy sectors. Russia's recent ratification of the Kyoto Protocol paved the way for the document to enter into force in early 2005. Now Annex I countries are obliged to fulfil their Kyoto commitments, and instruments such as CDMs, joint implementation and carbon trading will be operational. The role of cities and especially of urban transport is very important in reducing carbon emissions because transportation a major GHG-emitting sector.

chapter THREE

Nepal's national context

Photo: Dilip K. Munankarmi

Nepal is a land-locked country dominated topographically by mountains.[10] Sandwiched between two Asian giants, India and China, its 147,000 sq.km is home to 24 million people.[11] Its gross domestic product (GDP) was 5.8 billion US$ in 2003, and, with a per capita GDP of 240 US$, the country is one of the least developed countries in the world.[12] Agriculture is a major contributor to GDP, but in the last decade, the share of non-agricultural GDP increased to about 50-60%.[13] The country is largely rural: just 14% of its population lives in urban areas.[14] The urban population is concentrated in a few cities, notably the five in Kathmandu Valley, where 30% of the total population live.



Source: Economic Survey, 2004

Note: GDP figures are at factor costs and curves are smoothened. * Revised estimate; ** Preliminary estimate

Figure 3.1 Real GDP growth at constant 1994/95 prices

10. About 77% of the land mass is covered by hills and mountains
11. The 2001 national census figure is 23.214 million (Central Bureau of Statistics). The estimated population in 2004 was 24.74 million (Economic Survey 2004, Ministry of Finance).
12. Data from the fiscal year 2002/2003 is used. GDP at current prices (factor costs) is 435.531 billion Rs. (statistical Table 1.1). The population is 24.2 million and the exchange rate, 75.1 Rs. per US$ (Table 1e). See Economic Survey 2004.
13. Agriculture accounted for 39% of the GDP in the fiscal year 2002/03 (from Economic Survey 2004).
14. The urban population is expected to reach 20% by 2015.

The mountainous terrain poses a significant barrier to the development of a road- and rail-based transportation system in the country as building such an infrastructure demands considerable technical skill and physical labour and is capital intensive. Not surprisingly, the per capita total road availability is lower than that of Nepal's South Asian neighbours; it a mere 0.64 meters, only one-third of which is black-topped.[15] One major feature of the country's roads is the low volume of traffic plying on them. Outside the Kathmandu Valley, the maximum number of vehicles along key routes to the Indian boarder is 2,500 to 3,000 vehicles per day. The average figure for key links in the Tarai (southern plains) is just 300-1000 and on main hill roads it is still less, at 100-200.[16] Ninety percent of passenger transportation on roads is provided by buses, most of which are run by private operators.

Administratively and politically, the country is divided into five development regions and 17 districts. The far- and mid-western regions are far less developed than the rest of the country. Although Nepal has used five-year national plans to direct the economy and the country as a whole since 1956, the government has found it difficult to balance income, economic growth and sound infrastructure development across the regions. In response to the macro-economic crisis[17] of the mid-1980s and pressure from the World Bank and IMF, the government implemented a Structural Adjustment Program (SAP) in 1986. A number of reforms in trade, investment, banking, finance and other areas have been made since then.[18] Nepal has adopted liberal investment policies and made efforts to attract foreign investment. The investment climate has not, however, improved drastically, and transport infrastructure remains particularly neglected. The majority of infrastructure projects, including road construction, are supported largely by international donors through either grants or loans. The revenue to expenditure ratio in the

15. As of July 2004, the total road length was 16,042 km, of which 4,658 km was black top; 4,037 gravel; and 7,347 fair weather.

16. "Report and Recommendations of the President to the Board of Directors on a Proposed Loan to the Kingdom of Nepal" for the Road Network Development Project, November 2001, Asian Development Bank Report RRP: NEP 29472.

17. GDP growth stagnated around 3%, exports stalled at 5% of GDP, and imports rose significantly to 17% of GDP in 1986/87.

18. "Economic Policy and Civil War in Nepal" by Kishor Sharma, Paper for the UNU/ WIDER (World Institute for Development Economics and Research). Conference on Making Peace Work, 4-5 June, 2004, Helsinki.

road sector has consistently fallen in recent years (see Table 3.1). The present leftist rebellion in different parts of the country has caused a rapid upsurge in rural-urban migration, a fact which, in view of the limited infrastructure of urban areas, will only increase the burden of absorbing them. Although statistics are not available, experts agree that signs of stress are distinctly visible in a number of cities and district headquarters.

The air quality in Nepal's major cities has worsened over the last decade. The levels of air pollution in Kathmandu, Biratnagar, and Birgunj are categorised as unacceptable in terms of human health considerations by WHO guidelines. In a few major cities, the contribution of motor vehicles to pollution has increased gradually in recent years. Realising an independent ministry was needed to look after environmental issues, the government established the Ministry of Population and Environment (MOPE) in 1995. It passed the Environmental Protection Act (EPA) and Rules in 1997. National Transport Policy 2058 was unveiled in 2001; this document includes a wide range of transport-related strategies and is well formulated. How well it is implemented, however, will be the true test of developing sustainable mobility. Vehicle emission standards for new vehicles follow EURO-I standards (see Annex I), but emissions standards for in-use vehicles are not very stringent; this duality reflects the fact that there are a significant number of old and inefficient vehicles in the transportation system.

The situation in India has a major impact on Nepal's transport and environment-related decisions such as emission standards, fuel quality, fuel prices and various taxes. The majority of vehicles in Nepal are manufactured in India, and Nepal buys oil from the state-owned Indian Oil Corporation. The largely

Table 3.1 **Expenditure on and revenue from Nepal's road sector (in million rupees)**

Item	1992/93	1993/94	1994/95	1995/96	1996/97	1997/98	1998/99
Expenditure	1,469	1,449	1,872	3,330	5,135	4,206	5,328
Revenue	1,351	1,428	1,744	2,059	2,321	2,483	2,656
Revenue/Expenditure	92%	98.6%	93.2%	61.9%	45.2%	75.1%	66.6%

Source: "Report and Recommendations of the President to the Board of Directors on a Proposed Loan to the Kingdom of Nepal" for the Road Network Development Project, November 2001, Asian Development Bank Report RRP: NEP 29472.

unregulated open border between Nepal and India renders the prices of petroleum products essentially the same in both countries. If Nepal adopted any standard higher than that in India, it would likely fail.

The Nepalese parliament passed the Local Self-Governance Act in 1999 to provide a legal basis for decentralised self-rule by locally elected bodies such as municipalities and village and district development committees (VDCs and DDCs). This Act grants city authorities the power to make decisions about infrastructure and environmental management, to enact by-laws, and to control local taxation. City authorities are gradually assuming a greater role and building their capacities, but, functionally speaking, key responsibilities that affect transportation infrastructure and urban environmental management decisions still lie with the national government.

Nepal's GHG emissions are relatively small. The country's first national communication to UNFCCC estimated net GHG emissions (CO_2 equivalencies) of 39 million tonnes in 1994/1995. Per capita emission is only 1.9 million tonnes.[19] The transport sector is not a very large source: per capita, it generates only 22 kg, six times less than in China and 180 times less than in the United States.[20] However, the transport sector contributes about one-third of the total CO_2 emissions from fuel combustion in the country.[21] These statistics are primarily attributable to Nepal's low vehicle ownership rates: Nepal had 59 people per vehicle and 348 people per car in mid-2004.[22] Motorcycles dominate motorised modes; cheap and widely used, they account for 62% of the total registered vehicles. In short, in both per capita and absolute numbers, Nepal's total GHG emissions and road transport emissions are insignificant compared to those of its neighbours. However, although the scale of motorisation is currently small, the rate of growth is rapid and the numbers of cars and motorcycles are skyrocketing. Experts suggest that GHG emissions from transport

19. This is net GHG emissions. CO_2 contributes only about 25%. See Nepal's First Communication to UNFCCC available at **http://www.mope.gov.np**

20. Nepal First National Communication to UNFCCC. CO_2 from transport in 1994/95 was 456 Gg, pp. 16. For comparison, China has 122 kg per capita, six times more than Nepal (CO_2 Emission from Fuel Combustion 1997-1998, International Energy Agency. 2000, Paris, pp. II.82-II.84).

21. The share of CO_2 emissions from the transport sector was 31% of the total fuel combustion in 1994/1995.

22. This figure represents the stock of registered vehicles. "Cars" means light-duty vehicles, including cars, jeeps, and vans. As of March 2004, the total registered vehicles reached 418,910: there were 70,897 cars, vans and jeeps and 262,067 motorcycles. Source: Economic Survey 2004.

could increase four-fold by 2030 if the present trend continues.[23]

Because Nepal's transport sector is currently not efficient in terms of either its energy use or mix of modes, there are many prospects for reducing CO_2 emissions. The future prospects (costs aside) for battery-operated electric vehicles (EVs) and electric transportation such as trolley buses and trains are good as electricity is provided by environmentally clean run-of-river hydropower plants. Russia's recent ratification of the Kyoto Protocol has given new life to flexible mechanisms like CDMs and financial mechanisms like a global environmental facility and other bilateral mechanisms will also open up possibilities. Nepal's transport sector may, for example, be able to accumulate certified emission reduction credits to supplement the growing financial burden of developing urban transportation infrastructures. The country recently entered into an agreement for a carbon off-setting program in the bio-gas sector with the prototype carbon fund of the World Bank; this contract alone, experts estimate, will generate five million US dollars in revenue inflow. Some key indicators of the state of Nepal's transport sector and environment are compared to those of neighbouring countries in Table 3.2.

23. National Communication of Nepal to UNFCCC, July 2004, pp. 46.

Table 3.2 Selected indicators of transport and environment for South Asian countries, 1997

	Bangladesh	India	Nepal	Pakistan	Sri Lanka
General					
Surface area (sq. km)	144,000	3,287,260	147,180	796,100	65,610
Total population	124,381,408	962,377,664	21,444,880	128,457,312	18,552,000
Population density (people per sq. km)	956	324	150	167	287
GDP per capita, PPP (current US$)	1,388	2,034	1,221	1,802	3,041
CO_2 emissions (mttonnesper capita)	0.19	1.07	0.13	0.73	0.41
CO_2 emissions (kg per PPP $ of GDP)	0.14	0.52	0.11	0.41	0.14
Urban population (% of total)	23	27	11	35	23
Transportation					
Per capita road availability (m)	1.6	2.6	0.62[a]	1.8	0.6
Roads, paved (% of total roads)	9.5	56.5	31[a]	44	95
Vehicles (per km of road)	0.6	3.0	16[b]	4.3	53.1
Two-wheelers (per 1,000 people)	1.2	26.7	5.2[b]	13.3	38.3
Vehicles (per 1,000 people)	1.0	7.7	9.9[b]	8.0	31.9
Passenger cars (per 1,000 people)	0.4	4.8	2.2 (all cars)[b]	4.7	14.1

Source: World Development Indicators 2004, The World Bank.
Data older than the most current data are used to make sure that all indicators are available for all countries.

a. Calculated by the author from the 1997 population of 21,331,362 (Nepal Population Report 2002, MoPE) and the road length for 1997/98 of 13,223 km (Economic Survey 2003/4).

b. The total number of vehicles in 1997/98 was 211,981. Vehicle Statistics, DoTM.

chapter FOUR

Kathmandu: A city experiencing rapid change

Photo: Dilip Munankarmmi

4.1 Population, urbanisation and land use

Surrounded by high mountains, Kathmandu Valley is home to three districts, Kathmandu, Lalitpur and Bhaktapur,[24] and the nation's capital, Kathmandu Metropolitan City, in Kathmandu District. Each district includes a core city area as well as rural territory which extends beyond the Valley into the hills and mountains. The Valley's five cities are so small and so interlinked that it makes no sense to separate them in analysis. The Valley houses a majority of Nepal's urban developments, all five of its municipalities, the majority of its total population and 30% of its urban population, and virtually all of the urban road infrastructure and transportation system of the three districts. The Valley exercises unparalleled political and economic power and is undergoing rapid societal transformation and modernisation.

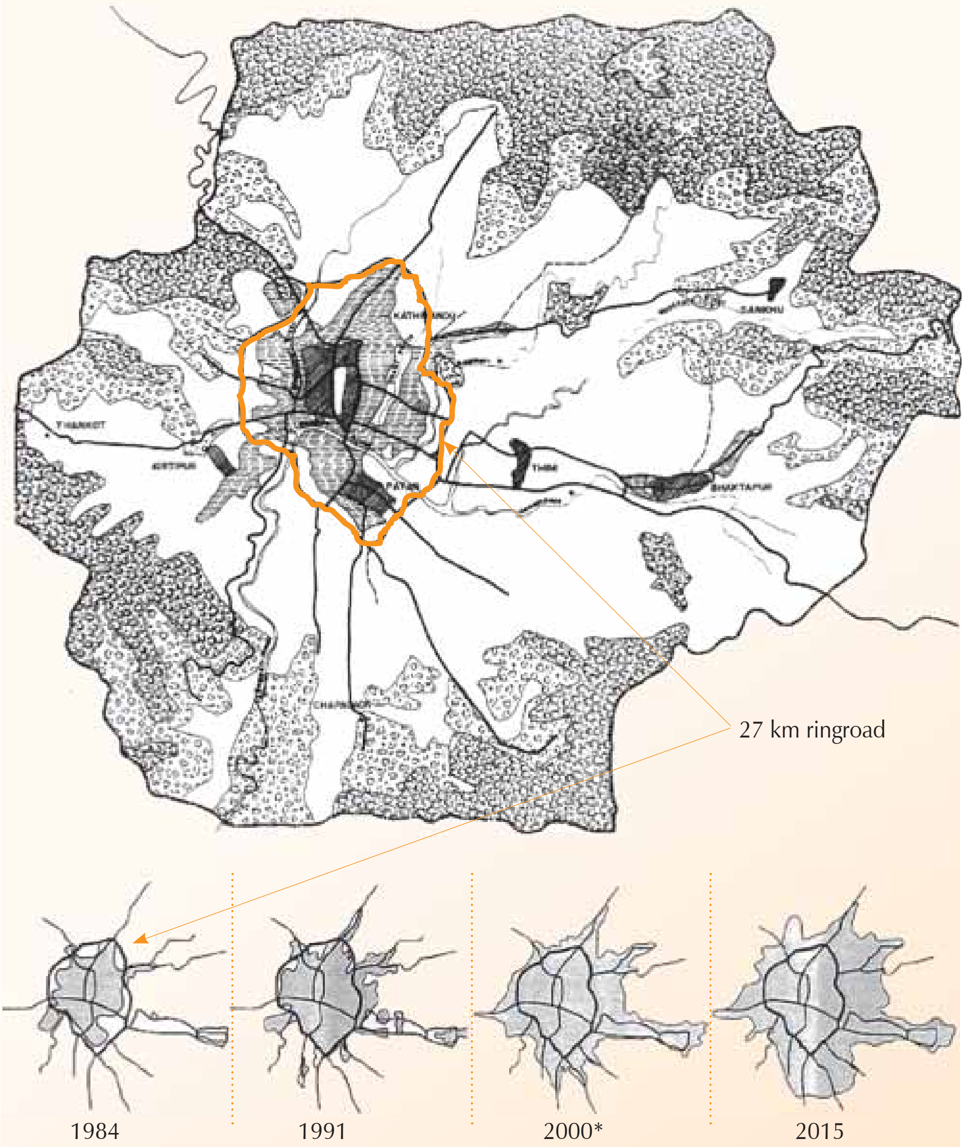
Kathmandu is home to one-and-a-half million people in its 666 sq. km area.[25] Three-quarters of the population lives in urbanised areas. Its average population density is 1,372 people per sq. km, but the density of core areas reaches 4,250.[26] To compare, its density is half that of Shanghai and less than a quarter of that of Delhi. The densest areas of Shanghai and Delhi are 15 and five times more dense than the densest areas of Kathmandu.[27]

24. Nepal is divided into 75 districts.

25. This figure (1.58 million) includes only the population of the three districts that resides within the Kathmandu Valley. The number was arrived at by excluding the populations of the 17 VDCs that belong to the three districts but are not within the physical boundaries of the Valley. The 2001 Census figure for the population of the three Valley districts is 1.64 million. The area of the three districts is 899 sq. km. The urban population is one million. However, a number of VDCs in the Valley are already urbanised yet not counted as part of the urban population because they fall beyond municipality boundaries. Including urbanised VDCs, the urban population is 1.21 million or 76% of the total. (Source: IUCN, 1999 pp. 115 and pp. 8, and Census 2001). The latest report issued by the Kathmandu Valley Town Development Committee gives the Valley area as 666 sq. km (See Development Plan 2020 of Kathmandu Valley) though previous studies used the figure of 640 sq. km.

26. The core area is Kathmandu Metropolitan City's wards nos. 12, 17-28 and 30, which together cover 2.75 sq km and house a population of 116,885. For details, see Joshi (2004).

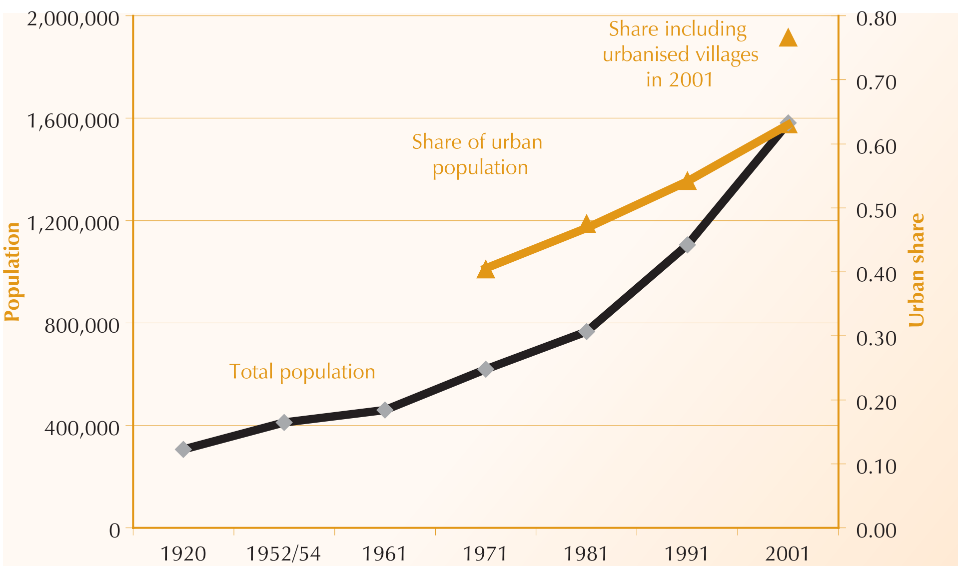
27. A tentative estimated based on a report by the Centre on Global Climate Change, Washington DC, 2001 and 2002.



Source: Courtesy of Pushpa Sundar Joshi and CDS (2001)

Figure 4.1 **Expansion of urban settlements in Kathmandu Valley over time**

Ancient Kathmandu was a small concentrated city with three major urban clusters and a few small towns near transportation corridors that linked the city to outlying regions. Its population in 1950 was four times less than its present population is and barely 40% of the total lived in urban areas.[28] When the country opened itself to the outside world in the 1950s, many development efforts were initiated, some of which involved developing motorable roads linking the city to other regions. Since then, and especially in the last two decades, Kathmandu suddenly entered a new phase—largely haphazard and uncontrolled urban settlement. Till 1984 its urban settlements were largely confined to within the 27-km Ring Road and to two major clusters, Bhaktapur and Kirtipur. Since then, however, it has expanded in almost all directions; the most rapid expansions are along transportation corridors (see Figure 4.2).



Note: The population show includes only those people who reside in the Valley. It excludes the population of those VDCs of the three districts that lie outside of the Valley. Source: IUCN (1999) and CBS (2001). In 2001, the urban share was 76% of the populations of urbanising villages, whose population growth is over 4%.

Source: Joshi (2004).

Figure 4.2 Population growth in the Kathmandu Valley

28. See IUCN (1999) pp.115. The 1952/54 population was 410,995 with 196,777 in urban areas

Migration from other parts of the country has played a major role in contributing to the high population growth rate of Kathmandu in recent decades. It registered a moderate average annual population growth rate in 1961/71 (about 2%). Since then it has doubled, recording an over 4% annual average growth rate over the decade from 1991 to 2001. Most of the growth taking place is outside the historical core areas. In the large municipalities of Kathmandu and Lalitpur, the population growth rate is decreasing due to the saturation of physical space. In a few core areas negative growth has been observed.[29]

Past studies predict that the population of Kathmandu will continue to increase drastically from the 1.58 million who presently live there. A recent estimate in Development Plan 2020 of Kathmandu Valley predicts that the population will double, reaching 3.3 million, by 2031. In fact, some urban population projections for 2015, like those of the Kathmandu Valley Urban Development Plans and Programs (KVUDPP) carried out with the ADB's support in 1991 and "Regulating Growth: Kathmandu Valley" carried out by IUCN and HMGN in 1995, were surpassed in 2001.

There have been phenomenal changes in the land-use patterns of the Valley in the last few decades. The share of agriculture land was 64% in 1984; in 2000, it was just 41% (KVTDC, 2002)[30] as conversion into built urban infrastructures continued. In contrast, the amount of forested land has not changed significantly. Past development plans repeatedly advocated a containment policy which would control sprawl, increase urban density inside the present Ring Road, preserve the surrounding agricultural land, and maintain the ecological balance of the city. Despite this goal, the city has sprawled, extending on all sides, but mostly along its transportation corridors. The result is increased pressure on urban planning, infrastructures (such as roads) and environmental services (like sewerage and waste management).

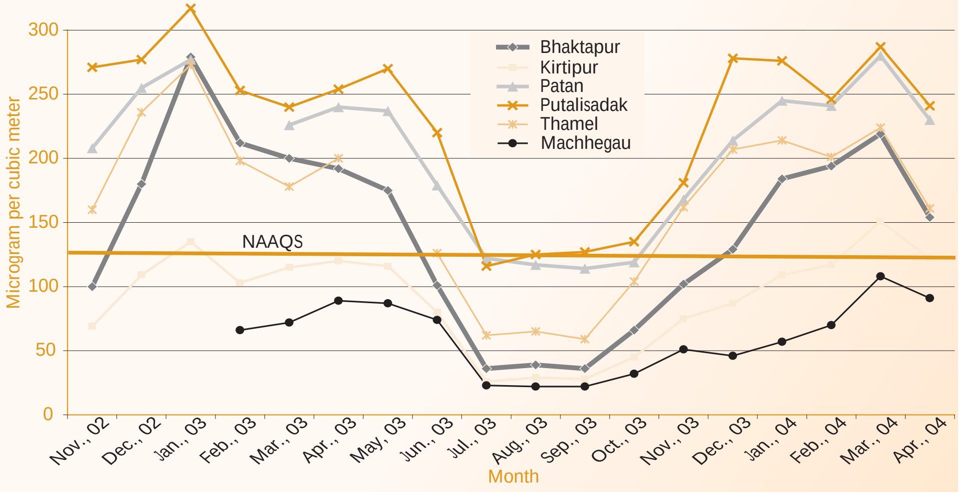
29. Twelve of the 35 wards in Kathmandu Metropolitan City have population growth rates of less than 3%.

30. This plan was approved by the national government in August 2002. Owing to the political stalemate in the country, no proper institutional arrangement for their implementation had been devised as of 2004.

4.2 Air pollution

Section 1.3 outlined the past air pollution problems of the Valley. The levels of air pollutants, especially PM_{10}, are significantly above the healthy limits set by the WHO. Dust re-suspension due to motor vehicles and construction, smoky vehicles, and the release of PM by small-scale industries such as brick kilns are major sources of air pollution. Data collected by road-sides and on holidays demonstrates that motor vehicles are the primary source.

Since October 2002 air pollution in six sites in the Valley has been monitored using automatic air pollution monitoring stations. The sites include one suburban site, one mixed residential and commercial site, two heavily congested road-side sites and two localised urban centres (Bhaktapur and Kirtipur). The results show that levels of PM_{10} are alarmingly high along roadsides: they exceed the NAAQS of 120 $\mu g/m_3$ (24-hour average) 75% of the time, especially in winter months, when dispersion is low. In the peak months between December and March, PM_{10} concentrations reach as high as two times the NAAQS. Figure 4.3 shows the trend of PM_{10} concentrations in the monitored



Source: Received through personal communication with MOPE in July 2004. (Courtesy of Bhai Raja Manandhar). The two sites whose values are lower than the NAAQS are the suburbs.

Figure 4.3 PM_{10} **concentrations in the Valley**

sites. The data also shows that the weekly average SO_2 concentrations in Bhaktapur are sometimes above the NAAQS, especially during the winter, when old, fixed brick kilns operate. Recently, however, the government has prohibited such kilns; it now promotes vertical shaft brick kiln technology, which reduces pollutants significantly.

4.3 Transportation picture

Road transportation is the only means of travel in the Valley at present and into the foreseeable future.[31] The transportation system in the Valley is characterised by inadequate road length, narrow and congested roads, unmanaged traffic, an inadequate traffic management infrastructure, a combination of old and new vehicles, and a multimodal public transportation system (from three-wheelers to buses) in which the role of high-occupancy public transportation is growing increasingly marginalised. In the last two decades, limited improvements have been made in traffic management, emission control, and public transportation promotion, but they are offset by the declining role of high-occupancy public transport, rapidly rising transportation activity, and the growth in the number of private cars and motorcycles.

4.3.1 Road infrastructure

The 27-km Ring Road circumscribes the main city area and connects all major radial roads, which are linked to rural settlements or provide transportation corridors to highways or neighbouring cities. Nepal has five categories of roads: national highways, major and minor feeder roads, district roads and urban road. Kathmandu Metropolitan City classifies its roads based on the number of lanes and width. The largest, a *path*, has at least four 3.5 meter-wide paved lanes, while the smallest, a non-motorable *galli*, is less than three metres wide. In 2001, the Valley had 1,331 km of roads.[32] The density was 1,232 people per km of road[33] or about two km of road per sq. km of land.[34] KVTDC (2002) reported that this amounted to between five and six percent of the net developable

31. There are no plans to develop a rail-based transport system, and there has been no discussion of this option either.

32. Road Statistics 2001, Department of Roads. The actual road length in the Valley is slightly less. This data is the sum of the road lengths of the three districts.

33. In 2001 the population of the three districts was 1.64 million.

34. Assuming that almost all roads are located inside the 666 sq. km Valley floor. The area of the three districts is 899 sq. km.

land, a low but not atypical figure for the capitals of many developing countries. Only about 54% of the total length of roads is paved and almost 24% is neither paved nor gravelled.

4.3.2 *Travel characteristics*

The number of studies which characterise the travel patterns in the Valley is limited. While information on the detailed travel behaviours of travellers and factors that affect their choice of modes is unavailable, the modal split of peak hour travel reveals that the majority of demand is met by public transportation (see Table 4.1). Public transport vehicles (which comprise 19% of the total) meet 57% of travel demand while motorcycles (which are great in number) meet just 6% of travel demand. The share of non-motorised modes in peak-hour travel demand is significant (22.4%).

4.3.3 *Vehicle ownership trends: structure and type*

About 57% of the total vehicles registered in the country are registered in the Kathmandu Valley.[35] In the case of passenger cars and motorcycles, the figures are 68% and 64% respectively. The fact that these figures are so high suggests that the Valley plays a significant role in shaping the transportation policy of the whole country. In the 15 years from 1989 to 2004, the number of registered vehicles increased 6.8 times to reach 249,282 in July 2004. Vehicles include private cars, jeeps, pick-ups,

Table 4.1 Peak-hour modal split in Kathmandu Valley

Mode	Average peak-hour modal split				% of daily passenger travel
	No. of vehicles	*No. of passengers*	*% of vehicles*	*% of passengers*	
Public transportation	5289	93872	19.3	63.5	56.5
Motorcycle	11633	15123	42.5	10.2	5.8
Passenger car and taxi	4457	7593	16.3	5.1	5.3
Bicycle	5996	5996	21.9	4.1	4.3
Pedestrian		25349		17.1	18.1
Total	**27375**	**147933**	**100.0**	**100.0**	**100.0**

Source: Passenger Travel & Modal Split Estimation of Kathmandu Valley, Broersma, K and N Pradhan, Mission Report 4, Kathmandu Valley Mapping Program, Kathmandu Metropolitan City/European Commission, Kathmandu, 2001. (Kind courtesy of Mr. P.S. Joshi)

35. Source: Vehicle statistics available from the Department of Transport Management. All vehicles registered in the Bagmati Zone are assumed to be used in Kathmandu. This is a reasonable assumption because other districts in this zone are hilly areas and largely un-motorable.

vans and microbuses, buses, mini-buses, trucks, three-wheelers and motorcycles. The annual average growth rate of the total registered vehicles in the Valley in 1990-2004 was over 13% (See Figure 4.4). The growth rate of motorcycles is particularly high, over 17%, and rising very rapidly, owing to their low cost and high mobility on congested and narrow roads. The growth rate of cars, vans and jeeps (light-duty vehicles) is the next highest. Registered taxis number about 7,500 (Ale, 2004). Since 2001, there has been a dramatic rise in new registrations of motorcycles. The reason is not known but could be due in part to various financial options offered by local financial institutions and motorcycle distributors. Statistics show that the proportions of various modes of transport used has changed significantly in the last 15 years and that motorcycles now dominate.

Another important issue is the number of old vehicles, though this number is difficult to state with confidence. The estimate given here is based on various assumptions made regarding the data of previous studies and this study. The DOTM reported in 2004 that the new government policy (which has not yet been implemented due to pressures from transport entrepreneurs) of banning vehicles older than 20 years would affect about 10,857 vehicles (including 5224 small private vehicles, 2600 large public vehicles, and 1200 government cars) in the Valley.

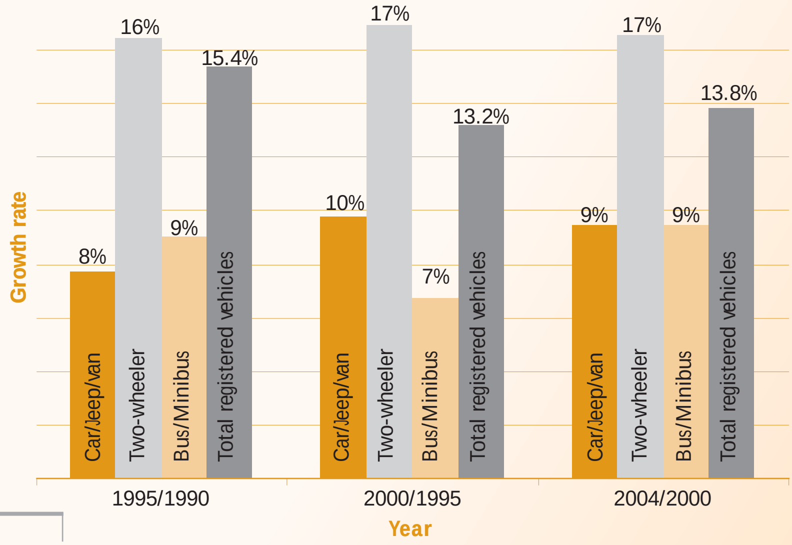


Figure 4.4 **Average annual growth rates of vehicles in the Kathmandu Valley**

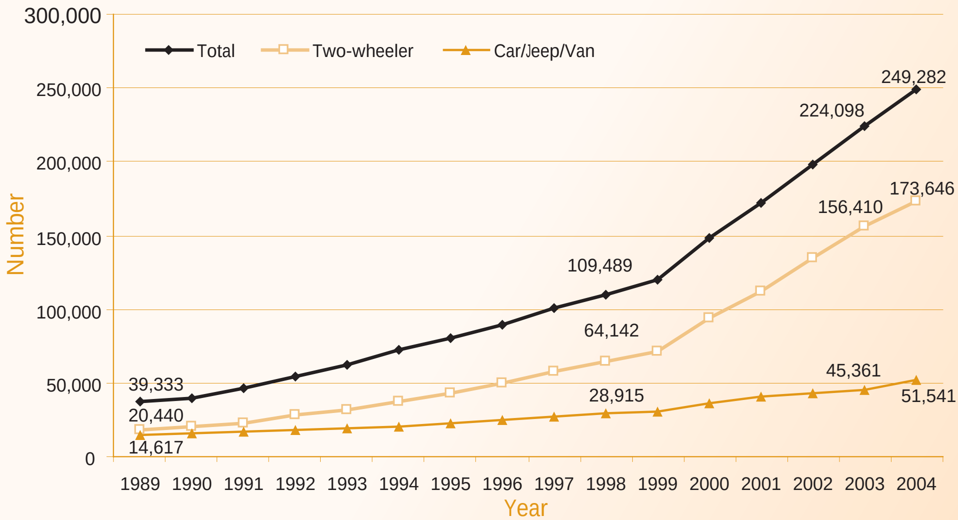


Figure 4.5 **Increase in the number of registered vehicles in the Kathmandu Valley**

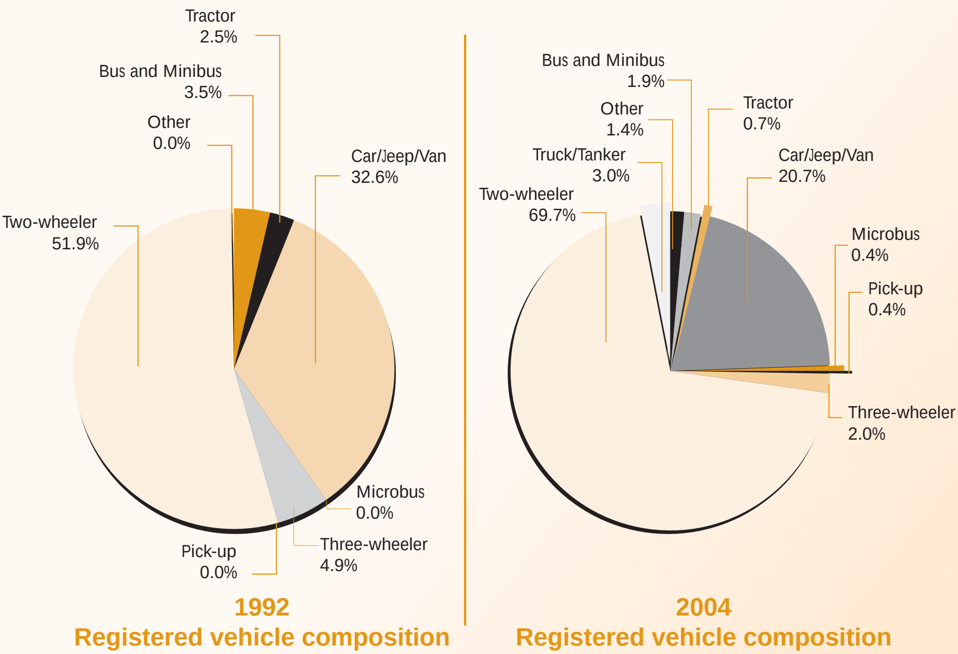


Figure 4.6 **Composition of the registered vehicle population in the Kathmandu Valley**

However, this is not necessarily the actual number of operational vehicles that will be displaced (there is a history of bargaining with the government to get tax breaks for replacing old with new vehicles; this policy encourages owners to claim tax breaks for non-operational vehicles to cover the cost of replacing them). Ale (2004) reported that about 43% of the nation's total of registered buses and minibuses (2,339) operate in the Valley. As shown in Figure 4.7, data on registrations provides an image of the age of vehicles. The share of older vehicles could be significantly smaller than is shown but caution should be taken as the share of new vehicles is inflated by the rise in the number of motorcycles.

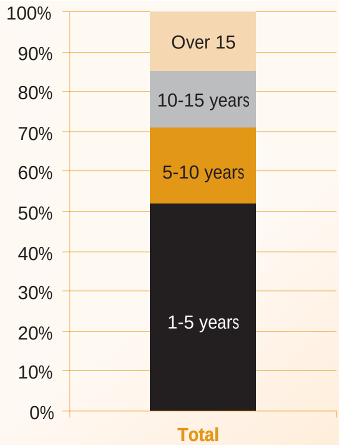


Figure 4.7 **Age of registered vehicles in 2004**

(Caution: This is not the number of operational vehicles)

Most of the newly added private cars are Indian models between 800 and 1,300 cc. All motorcycles registered after 2002 are four-stroke motorcycles, which emit significantly fewer air pollutants than do two-stroke motorcycles.

4.3.4 State of public transport

Public transportation is provided by a mixture of low- and high-occupancy vehicles. About 2,339 buses and minibuses, one thousand LPG and electric battery-operated three-wheelers, one thousand LPG, gasoline and diesel microbuses, and six to seven thousand taxis make up the public transport system in the Valley. Public transport serves about 57% of the total passengers during peak hours. Almost all public transportation is provided by the private sector. The state-owned *Sajha Yatayat* and electric trolley buses are almost on the brink of collapse due to management problems. Only three electric trolley buses and very few Sajha Yatayat buses were in operation in 2004 though plans to revive trolley buses are being made with the help of the private sector. A study demonstrates that it is feasible to operate trolley buses on the Ring Road (CEMAT, 1999).

In 2004, 5,085 three-wheelers were registered. By July all gasoline models had been banned. After 1992 no registration of diesel three-wheelers was allowed and this type of vehicles was completely phased out in 1995. Since then, the use of battery-operated electric three-wheelers has risen due to the efforts of the government, NGOs and donor communities. In 2000 there were about 600 EVs and a Rs. 500 million industry comprised of vehicle manufacturers, battery-charging stations and vehicle operators had been established (IGES, 2004). Since then the industry has stalled due to competition in the market, mostly from microbuses with long routes. At present, there are about one thousand, half battery-operated and half LGP-powered vehicles. In core city areas, microbuses and minibuses dominate public transportation; they are convenient for passengers but collectively take up more road space than buses do. The typical seating capacities of public transportation vehicles are shown in the Table 4.2.

To counter the dominance of low-occupancy public transportation vehicles, rapidly rising numbers of private cars and motorcycles, heavy traffic congestion, and pollution problems, it is essential to reform public transportation through the promotion of high-occupancy vehicles. A policy dialogue carried out as part of this study reached this conclusion, but awareness amongst decision-makers about the urgent need to restrain private transportation and promote high-occupancy public transportation is low.

4.3.5 *State of vehicular traffic and management*

Since a JICA study was conducted in 1991/92 (see JICA, 1993), no other systematic study of vehicular traffic in the Valley has been carried out. However, ground realities have changed significantly since 1991 as the most dramatic changes in urban transportation have taken place

Table 4.2 Typical seating capacities of public transportation in Kathmandu Valley

Vehicle type	Seating capacity
Large buses	40+
Minibuses	25-30
Microbuses	14-16
Three-wheelers	12-14
Electric three-wheelers	11

within the last decade. There are no reliable statistics, for example, on current average traffic speed. Some old studies (Devkota, 1992; JICA, 1993) conducted in the early 1990s report an average speed of 20-30 km per hour but speeds have visibly declined in recent years and traffic jams are frequent in key central areas. New estimates suggest that average speeds are less than 20 km per hour (Ale, 2004). Some traffic lights have been introduced in recent years (at present there are lights at 11 junctions, 10 of which the Japanese Government supported, and in over 60 junctions traffic police manually control traffic), yet unmanaged pedestrian movement and crossings and non-compliance with traffic rules hinder flow and the lack of overhead passes is a serious infrastructural shortcoming. Recent data shows that 590 traffic police personnel are responsible for managing traffic in the Valley; of them, just 70% are trained. The average number of hours of duty is as high as 12 in 24.[36]

4.3.6 Trend in traffic accidents

The number of traffic accidents reported to the traffic police is, naturally, less than the actual number. Since few car owners and drivers have vehicle accident insurance, usually only unsettled cases and big accidents are reported. Nonetheless, the official statistics

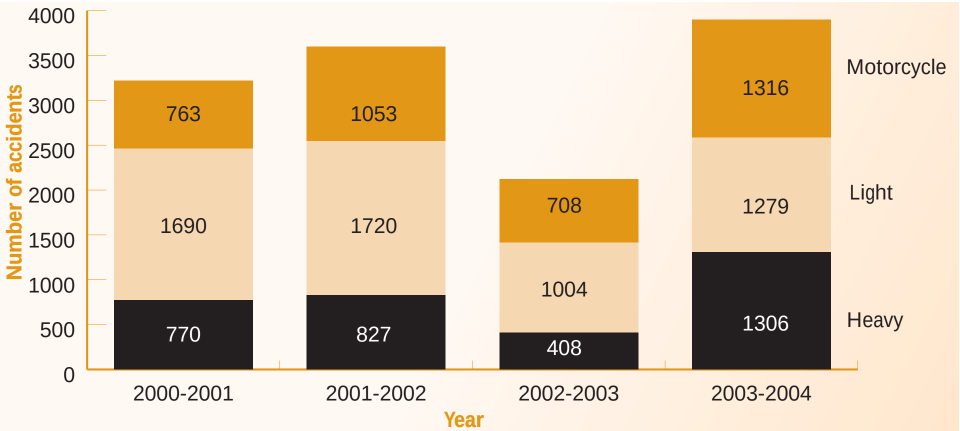


Figure 4.8 **Trends in the number of traffic accidents in the Valley[37]**

36. Personal communication with Valley Traffic Police Office.

37. Based on presentation by the Deputy Superintendent of Police, Mr. Govinda Niraula, entitled "State of Traffic Management in the Kathmandu Valley" at the Roundtable Workshop on Strategies to Mitigate Air Pollution from Urban Transportation in Kathmandu Valley, 29-30 July, 2004, Park Village Resort, Kathmandu. Organised by the Institute for Global Environmental Strategies (IGES), Japan, in collaboration with MOPE.

for 2004 do show that the number of accidents is on the rise. About 35% of accidents occur at night. Trucks and buses, mainly those travelling on highways, account for 45% of accidents, while small vehicles on city roads account for 42%. Motorcycles have the highest accident rate.

4.3.7 *Carbon-friendly transport*

As discussed earlier, a Valley priority is to combat air pollutants and dust, specifically PM_{10}. Any resultant mitigation of CO_2 emissions is a benefit in a real sense. The choice to maximise CO_2 benefits when implementing air pollution mitigation measures needs to be considered. Two questions arise: "What does it take to choose carbon-friendly air pollution mitigation measures?" and "Is it possible to implement such measures?".

Improving energy efficiency is one measure that can reduce air pollution and CO_2 emissions. For a country like Nepal, which is fully dependent on foreign oil, utilising indigenous energy sources and saving foreign exchange are equally important. Typical energy-centred air pollution mitigation measures, such as improving fuel efficiency, implementing better inspection and maintenance programmes, phasing out old vehicles, increasing traffic speed, and promoting public transportation, all aid in CO_2 mitigation. However, not all air pollution measures can reduce CO_2 emissions; tail-pipe emission control strategies are especially ineffective.

The promotion of EVs can reduce CO_2 emissions. The growth of the battery-operated three-wheelers so popular in the late 1990s has stalled since 2000, but several studies demonstrate that EVs, whether three-wheelers or trolley buses, are feasible. Some even believe that driving conditions in the Valley are suitable for electric cars such as the India-manufactured REVA.[38] Since electricity is generated by run-of-river hydropower plants, the use of EVs can reduce air pollution as well as reduce oil imports and mitigate CO_2 emissions. EV use can also help to improve the load factor of power generation and to reduce the average cost of electricity by making possible the use of otherwise wasted off-peak-hour energy.[39] An EV-based approach, if integrated well with policies to restrain private cars, promote high-occupancy public transportation and improve energy efficiency, can make a big improvement. The fact that Kathmandu already has experience with EVs is promising.

38. See Pradhan (2004), Bhatta and Joshi (2004), Dhakal (1996), Dhakal (2003a), CEMAT (1999).
39. Dhakal (1996)

4.4 Emissions from motor vehicles

Table 4.3 Emission standards for in-use vehicles (2000)

Fuel	Vehicle type	Model year	CO, %	HC, ppm	HSU[40], %	Test
Petrol	Four-wheeler	Up to 1980 After 1981	4.5 3.0	1000	-	Idle
	Three-wheelers	Up to 1991 After 1992	4.5 3.0	7800	-	Idle
	Two-wheelers	All	4.5	7800	-	Idle
LPG/CNG	All categories	-	3.0	1000	-	Idle
Diesel	Four-wheelers	Up to 1994 After 1995	-	-	75 (k[41] = 3.22 m-1) 65 (k = 2.44 m-1)	Free acceleration

Source: www.mope.gov.np/environment/green.php. Accessed on July 20, 2004.

The country introduced emission standards for new vehicles equivalent to EURO-I (Nepal Vehicle Mass Emission Standard, 2056) effective from January 2000. In-use vehicles, however, continue to pose a serious challenge because inspection and maintenance programmes in the Valley are weak. At present only vehicles with green stickers can ply inside the Ring Road and spot-checking of emissions is frequently done by traffic police in coordination with the DOTM, which together run three emission-testing stations. All commercial vehicles are tested twice a year and all other vehicles are tested once a year, irrespective of their age. Road-side tests demonstrate that failure rates, even among cars with green stickers, are high (more than 20% of all tested vehicles and up to 70% of diesel vehicles fail). The non-compliance fee is nominal and there is no proper system for getting non-complying vehicles repaired. The improper maintenance of vehicles, overloading, poor road and transport infrastructures, and fraud and corruption are often cited as major obstacles to emission management. Studies note that the prevalence of two-stroke engines such as motorcycles and three-wheelers and low scrapping rates are other major problems (SOMEN, 2001). Loopholes in the inspection system are a third difficulty. Ale and Nagarkoti (2003) reported that tampering with carburettors and injection pumps is common and that vehicle owners do not get proper repairs done. Instead, they have temporary adjustments made just to pass emission tests. Bribing officials is another impediment to emissions control.

40. HSU (Hatridge Smoke Unit) is the percentage opacity measurement for a column of smoke 430 mm high.

41. "K" is the coefficient of light absorption, a measure of the "blackness" of smoke. It is independent of the measurement length.

Fuel choice and quality influence tail-pipe emissions. Because Nepal buys its petroleum products from India, its fuel quality is influenced by fuel quality in India. Ale (2004) reported that the gasoline now used is lead-free and 0.2% sulfur while diesel is 0.25% sulfur. India adheres to BIS 2000 Specification for Gasoline and Diesel[42] but will soon improve fuel quality to meet Bharat Stage II emission norms. In 2002, India unveiled its Auto Fuel Policy, which proposes various fuel qualities and a road map for meeting the emission reduction objectives of EURO-III and EURO-IV equivalents in the future. India's efforts will have a significant impact in Nepal.

4.5 Policies and institutional arrangements for managing emissions from motor vehicles

A number of initiatives have been taken in the past to combat rising air pollution in Kathmandu Valley, especially that from automobiles. Some are given below.

- The government first responded to the growing problem of air pollution in Kathmandu Valley by stopping the new registration of three-wheelers in November 1991.
- The government set emission standards for in-use vehicles in 1994 (65 HSU for diesel vehicles and 3% CO by volume for gasoline vehicles[43]) as part of the UNDP-assisted Kathmandu Valley Vehicular Emission Control Project (1992). Green stickers were given to vehicles which met emission standards.
- MOPE was established in 1995.
- EPA 2056 and Rules were enacted in 1997.
- In 1998, the government formulated NVMES in 2056; these standards, equivalent to EURO-I emission norms, went into effect from January 2000. All new vehicles imported since then have had to comply.
- In 1997 the government provided subsidies to battery-operated electric three-wheelers in the form of tax breaks.
- In 1999, the operation of diesel three-wheelers was banned in Kathmandu Valley, Pokhara

42. See "Report of the Expert Committee on Auto Fuel Policy," Government of India, August 2002. Downloaded from the web-site of the Ministry of Petroleum and Natural Gas at http://petroleum.nic.in/afp_con.htm on July 20, 2005.

43. This was later loosened. For motorcycles, 4.5% CO was set in early 1998. It was further revised in 2000 to add LPG and other vehicles (see Table 4.3 for details).

and Lumbini. About 600 diesel-operated three-wheelers stopped operating in the Valley. Owners were given tax incentives to buy other vehicles.

- In November 2000, the government announced a ban on all public vehicles older than 20 years and all vehicles in Kathmandu Valley having two-stroke engines. The policy was to be effective from 16 November, 2001, but the government was unable to implement the decision.
- The registration of new two-stroke motorcycles was curbed in late 2000.
- The emission standards of in-use vehicles were further improved after 1998 to include HC- and gas-operated vehicles such as LPG and compressed natural gas (CNG) in 2000. Earlier, LPG vehicles had not been subjected to emission standards and enjoyed clean vehicle benefits.
- In July 2001, while releasing the national budget, the government announced a 10% additional vehicle tax per year on vehicles older than 15 years. This is the first time a tax was linked to vehicle age and, although it did so weakly, it did try to discourage the use of older vehicles through fiscal instruments.
- The National Transport Policy 2001 was endorsed in the Ninth Five-Year National Plan (1997-2002). This policy is directed primarily towards infrastructure development but there are key provisions related to cleaner transportation systems, too. The outcome of this policy document is not yet clear.
- In 2003, the NAAQS for various air pollutants was introduced.
- From July 2004, two-stroke three-wheelers were banned in the Valley. The provision to ban 20-year-old vehicles has yet not been implemented, however.
- Apart from its transportation-related emission, recently the government banned polluting bull's trench kilns from Kathmandu Valley, one-and-a-half years after first announcing i would.
- The government also decide to move the now defunct Hima Cement Factory outside th Valley.

chapter FIVE

Analytical framework

Photo: Manish Koirala

5.1 ASIF framework

The analyses carried out in this study use the ASIF framework outlined in "Flexing the Link between Transport and GHG Emissions" (Schipper *et al.*, 2000). The framework is based on a simple decomposition of emissions into pre-defined factors, where emissions are the function of travel (activity), transport mode (structure), energy (intensity) and fuel. This approach has been used widely in the past by end-use modellers to consider energy, and air pollution and GHG emissions. A simple illustration of a decomposition for emissions from cars can be shown as

Emissions from cars = (emissions per unit of energy use) x (energy use per passenger-km of travel) x (pass-km of travel per vehicle-km travelled) x (vehicle-km of travel per vehicle) x (number of vehicles)

The above equation provides an easy but powerful framework and includes a variety of factors that are influenced by strategies and policies. When we aggregate this framework for all travel modes, it becomes,

Total emissions = Sum of emissions by all transport modes.

The broad decomposition follows:

GHG emissions = a function of (travel activities), (structure of travel mode), (intensity of energy use), (fuel quality and choice)

E = F (A, S, I, F)

In the ASIF framework, A and S deal mostly with behavioural and lifestyle aspects while I and F deal with technology aspects. Interventions in AS are possible in the long-term and need consistent action over time. Assessments made by researchers show that the cities in Asia have had limited success in intervening in AS though there are limited good experiences' such as those in Singapore. In contrast, intervention in IF is short-term and widely adopted for air pollution control in Asian cities. A reasonable balance of interventions in AS and IF, which is usually necessary, is rarely practised (Dhakal and Schipper, 2005).

Table 5.1 Factors and challenges in the ASIF framework

Components	Major factors or determinants	Related options
AS	• Income • Rate of urbanisation • Urban form • Urban functions • Rate of motorisation • Non-motorised modes • Modal mix, para-transit • Utilisation rate of personalised modes • Other	• Reorganising urban activities towards reducing needs to travel by motorised modes • Improving the efficiency of public and mass transportation • Limiting personalised transport such as cars and motorcycles and their rate of use • Reducing congestion by increasing the efficiency of transport infrastructure • Other
IF	• Energy efficiency of modes and vehicles • Size, engine type and age of vehicles • Occupancy rates (capacity mix and utilisation) • Congestion • Fuel quality: lead, sulfur content, reformulation, octane enhancements • Fuel choice: CNG vs. diesel, electricity, gasoline, bio-fuels • Emission control technologies • Other	• Controlling tail-pipe emissions through emission control technology • Improving energy efficiency of existing vehicles and of other travel modes • Choosing alternative fuels such as electricity, CNG, bio-fuels and making them cost effective • Improving I&M systems for in-use vehicles • Banning decades-old vehicles and promoting fuel efficient vehicles • Other

Figure 5.1 shows the factors likely to be associated with each of the components of ASIF in the case of the Kathmandu Valley. This study, considers the emission of CO_2 as well as the following other air pollutants are considered: CO, HC, NO_x, SO_x, TSP and PM_{10}.

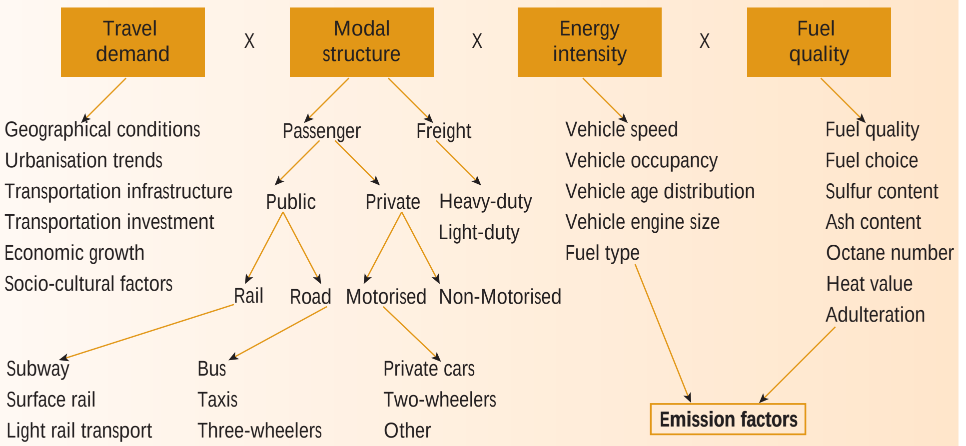


Figure 5.1 Structure of the study components

5.2 Methodology and data

The above-mentioned analytical framework was implemented through a number of spreadsheet models and long-range energy alternative planning (LEAP) software (see details in Section 5.2.2). This study considers only passenger transport. Historical analyses of energy, travel demand and emissions were carried out using Excel spreadsheets, while analyses related to the future were carried out using LEAP software.

5.2.1 Past trends

This study estimates the past trends in energy consumption and pollutant emissions from passenger transportation based on numbers of vehicles and other determining factors such as emission factors, annual average vehicle travel and fuel economy. This methodology was used extensively in past studies of the transportation sector.

Vehicles on the street, Vi(t), are estimated from vehicle registration data obtained from the DOTM and from operation factors, or the share of operational vehicles in the total stock of registered vehicles (see Appendix). Emission factors, EFij(t), are estimated from published literature; and average fuel economies of vehicles, Fi(t), are obtained from past surveys carried out by the author (Dhakal, 1996) and other published literature (Shrestha and Malla, 1996; Bose and Srinivasachary, 1997; Pradhan, 2004). Because of data constraints, VKTi(t) and EFij(t) are assumed to be the same for all past years but Fi(t) is changed over time. These data render the model relatively static in nature for historical analyses. Establishing precise emission factors is a major problem as no emission tests have yet been carried out on the urban driving cycle of Kathmandu. As a result, this and all past studies are constrained by their

$$E_j(t) = \sum_i V_i(t) \times VKT_i(t) \times EF_{ij}(t) \times F_i(t) \quad (1)$$

$$\text{Travel demand }(t) = \sum_i V_i(t) \times VKT_i(t) \times \text{vehicle occupancy rate }(t) \quad (2)$$

$$E_j(t) = \sum_i \text{pass km}_i(t) \times (1/\text{vehicle. occupancy rate}(t) \times EF_{ij}(t) \times F_i(t) \quad (3)$$

Where, **Ej(t)** is the total emission of emission type **j** in year t by passenger transportation in tonnes, **Vi(t)** is the number of vehicles on the street, **VKTi(t)** is the average annual vehicle-km travelled by a vehicle of type **i** in year **t**, **EFij(t)** is the emission factor of pollutant type **j** of vehicle type **i** in year **(t)** in **g/l**, and **Fi(t)** is the fuel economy of vehicle type **i** in year **(t)** in **l/km**.

reliance on emission factors given in the existing literature, especially studies on Indian cities; fortunately, similarities in vehicle type, conditions, and fuel economy make it possible to extrapolate. Tables 5.2 and 5.3 below show the major data used in this study. Since data on the critical parameters of the model are borrowed from other literature, the results of the model are validated by comparing its energy consumption estimates with past energy sales data and with the results of other studies. Past trends in passenger travel demand and the modal split in passenger-km is estimated by equation 2 in a way similar to how equation 1 was used, including the number of vehicles, average annual travel and average occupancy rate (number of passengers per vehicle). Energy consumption by fuel type is estimated by removing the emission factors in equation 1.

Table 5.2 Critical parameters of the estimation of energy and emissions in 2000

		Registered vehicles[1]	Operation factor[2]	VKT[3]	Load factor[4]	Fuel efficiency, km/l (km/Kw-h for electric)[5]
LDV	**Total**	**53,442**				
	Private car/jeep	***39,800***	***0.80***			
	• Gasoline vehicle	35,820	0.80	16349	2.6	11.34
	• Diesel vehicle	3,980	0.80	16349	2.6	8.00
	Commercial	***9,367***				
	• Taxi	8,065	0.97	37125	2.6	10.60
	• Diesel microbus	902	0.97	37125	12	8.00
	• Mini microbus	-	0.90	37125	18	
	• LPG microbus	400	0.88	37125	12	8.00
	Government	***4,275***				
	• Gasoline car	3,206	0.80	24830	2.6	11.14
	• Diesel jeep	1,069	0.80	24830	2.6	8.90
Bus	**Total**	**2,214**				
	• Diesel	2,192	0.31	39600	50	3.90
	• Trolley bus	22	0.14	39600	50	0.75
Minibus	**Total**	**2,437**	**0.68**	**37125**	**30**	**5.40**
3-wheeler	**Total**	**5,085**				
	• Battery	650	0.91	32340	10	5.83
	• Petrol	3,175	0.64	32340	1.8	11.65

		Registered vehicles[1]	Operation factor[2]	VKT[3]	Load factor[4]	Fuel efficiency, km/l (km/Kw-h for electric)[5]
	• Diesel	669	-	32340	10	12.50
	• LPG	591	0.72	32340	10	14.70
Motorcycle	**Total**	**173,646**				
	• Two-stroke	38,202	0.70	10950	1.6	38.40
	• Four-stroke	135,444	0.70	10950	1.6	53.80

Sources:

1. The number of registered vehicles quoted is as of July 2004. In the original data available from the DOTM, the vehicle categorisations are very broad, namely, car/jeep/van, pick-up, microbus, bus, minibus, three-wheeler, and motorcycle. The numbers of vehicles by type of use (private, commercial, government, etc.) and fuel (gasoline, diesel, LPG, electric) have been disaggregated using various assumptions and past studies (see Dhakal (2003a), Dhakal (1996), JICA (1993), WECS (2000), Bhatta and Joshi (2004), Ale (2004), etc.). For motorcycles, 22% are assumed to be two-stroke. To estimate the number of three-wheelers with different fuel types, actual numbers of vehicles given in various reports and information obtained from the workshop that was organised as a part of this study were used. Out of the 22 existing trolley buses, only three are operational.
2. "Operation factor" is defined as the ratio of operational to registered vehicles. Operation factors for buses, minibuses, microbuses and three-wheelers are estimated using actual numbers based on route permits issued by the DOTM. Operation factors are high in some of the categories due to the large number of new vehicles.
3. All VKT data is taken from Dhakal (2003a) and SOMEN (2001).
4. "Load factor" is defined as the average number of passengers. All data are taken from Dhakal (2003a), which comes from mostly Bose and Srinivasachary (1997).
5. There is no reliable estimate of the fuel efficiencies of vehicles. There is no established urban driving cycle and no data comes from scientifically reliable test results. Instead, these data come from surveying drivers about their monthly fuel use and distance travelled and do not provide much information on fuel efficiency by type, age, engine size or the level of loading or on emission deterioration rates. These data have come from a variety of sources based on the expert judgment of the author: gasoline car/vans—WECS (2000); diesel car/jeep/vans—Pradhan (2004); taxis—WECS (2000); diesel and LPG microbuses—Pradhan (2004); government vehicles—WECS (2000); diesel buses—Pradhan (2004); trolley buses—Bhatta and Joshi (2004); three-wheelers—Dhakal (2003a), WECS (2000); motorcycles—Dhakal (2003a).

Table 5.3 Vehicle emission factors for different pollutants

		CO	HC	NO_X	SO_2	PM_{10}	CO_2
LDV							
	Private						
	• Gasoline	261.93	87.98	17.11	1.50	2.27	3984.8
	• Diesel	24.80	10.40	11.20	4.92	7.20	3440.0
	Commercial						
	• Taxi vans	261.93	87.98	17.11	1.50	2.27	3984.8
	• Diesel microbus	24.80	10.40	11.20	4.92	7.20	3440.0
	• LPG microbus	36.45	15.93	9.56	0.00	0.00	1620.0
	Government/semi						
	• Gasoline cars	261.93	87.98	17.11	1.50	2.27	3984.8
	• Diesel car/jeep	24.80	10.40	11.20	4.92	7.20	3440.0
Bus							
	• Diesel	24.00	11.10	35.61	4.92	11.70	3440.0
	• Trolley	0.00	0.00	0.00	0.00	0.00	0.0
Minibus	Diesel	24.80	10.40	11.20	4.92	8.10	3440.0
Three-wheeler							
	• Battery	0.00	0.00	0.00	0.00	0.00	0.0
	• Gasoline	248.60	155.40	2.20	1.50	5.83	3984.8
	• Diesel	28.13	15.75	162.50	4.92	21.00	3440.0
	• LPG	36.45	15.93	9.56	0.00	0.00	1620.0
Motorcycle							
	• 2-stroke	184.32	234.24	3.84	1.50	19.20	3984.8
	• 4-stroke	726.30	69.94	11.30	1.50	4.30	3984.8

Sources:

1. The emission factor for SO_2 is calculated based on the sulfur content of fuels. Gasoline is 1000 ppm and diesel is 3000 ppm. The density of gasoline is 0.75 kg/l; and of diesel, 0.82 kg/liter. The molecular weight of S and SO_2 are 32 and 64 respectively.
2. Emission factors for CO, NO_X, and HC are taken from Dhakal (2003a).
3. For PM_{10}, values are borrowed from World Bank (1997). In the case of three-wheelers and motorcycles, values are borrowed from the case of Delhi (see Michael Walsh, Impact of Fuel Conversion on Emission Levels of 2-3-wheelers, Reduction of Emissions from 2-3-wheelers, 5-7 September, 2001, organised by Asian Development Bank, Hanoi, Vietnam).

5.2.2 *Future projections*

LEAP, which was developed by Stockholm Environment Institute in Boston, is a useful tool for scenario analyses as it allows for comparing and analysing alternative scenarios systematically and easily through its various software functions. The ASIF structure can be built into LEAP software. Although LEAP is basically an accounting framework, users can also carry out sophisticated simulations. Because LEAP uses the concepts of sector, sub-sector, end-use and devices, demand and resource analysis can be carried out at each stage, from end-use to primary energy level. In this study, we limited our analyses to demand. For future projections, 2004 was selected as the base year and a planning horizon up to 2025 was considered at five-year intervals—2010, 2015, 2020 and 2025.

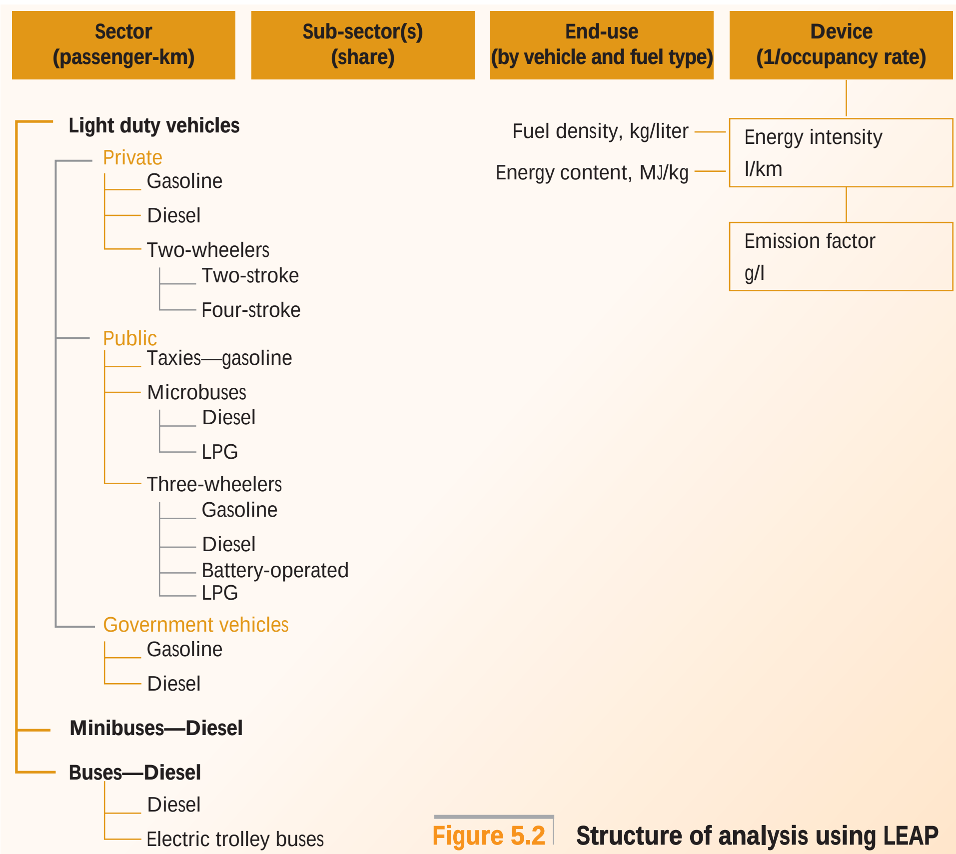


Figure 5.2 **Structure of analysis using LEAP**

In this study, sector, i.e. travel demand in passenger-km, is taken as the base level for aggregation. Travel demands up to 2025 were exogenously estimated using multiple regression analysis of past travel demand, past and future Valley population, and the past and future expected economic growth in Excel spreadsheet and then supplied to LEAP. The second level of aggregation is sub-sector, or the share of road and rail transportation in the total travel demand. The third level of aggregation is end use, or the split of travel demand among each mode as a share of the total demand. The fourth level is device, which is characterised as vehicle space per passenger (*the inverse of vehicle occupancy*) and energy intensity (fuel economy in l/km). Emission factors for CO_2, CO, HC, NO_x, SO_2, and PM_{10} are specified, in g/l. Scenarios were constructed for business-as-usual and alternative policies for the future, and the implications for energy demand and environmental emissions under these scenarios were analysed.

In this study, the future projections of travel demand were calculated using multiple regression analyses. The independent variables of the regression analyses were the future population of the Valley, the economic growth of the Valley, and time; the dependent variable was travel demand. The adjusted R2 of the regression was 0.87.44

In regression, population estimates were taken from CBS (2001) and IUCN (1999) and Gross City Products were estimated from projected national GDP (past GDP is taken from *Economic Survey 2004* and past volumes) and the 13% contribution of the Kathmandu Valley (based on JICA, 1993). It is assumed GDP will grow by 4% till 2007 and by 6.5% after that (this is a moderate scenario for GDP growth; scenarios for low and high rates of GDP growth will also be presented).

Although LEAP was used to analyse the future, two of the variables needed were estimated using Excel spreadsheets:

- Average future fuel efficiencies of the vehicle fleet by type of vehicle
- Average emission factors of the vehicle fleet by type of vehicle

This study estimates the average fuel efficiencies of the vehicle fleet with the help of spreadsheet models consisting of (1) the average fuel efficiency of the base year (2) fuel efficiencies of new vehicles (3) the addition of new vehicles into the fleet, and (4) the scrapping of 20-year-old vehicles. A roll-back method is used, as shown in equation 4. Similarly, the average emission factors for future years are estimated with the help of (1) the average emission factor in the base year, (2) the emission factor of newly-added vehicles, (3) the addition of new vehicles into the fleet, (4) the scrapping of 20-year-old vehicles (or 10-year-old vehicles in the case of three-wheelers and motorcycles), and (5) the emission deterioration rate of vehicles.

$$AFE_n = \frac{NVP_n \times NFE_n + [VP_{n-1} - NVP_{n-20}] \times AFE_{n-1}}{VP_n} \qquad (4)$$

Where, **n** is the year, **i** is vehicle age, $\mathbf{AFE_n}$ is the ***average fuel efficiency*** of the vehicle fleet in year **n**, $\mathbf{NVP_n}$ is the number of vehicles added in year **n**, $\mathbf{NFE_n}$ is the average fuel efficiency of vehicles added in year **n**, $\mathbf{NVP_{n-20}}$ is the number of vehicles retired in year **n**, $\mathbf{VP_{n-1}}$ is the number of vehicles in the previous year, $\mathbf{AFE_{n-1}}$ is the average fuel efficiency of the previous year, and $\mathbf{VP_n}$ is the total number of vehicles in year **n**.

$$AEF_n = \frac{NVP_n \times NEF_n + [VP_{n-1} - NVP_{n-20}] \times AEF_{n-1} + \sum_{i}^{15}(VP_{i-1}^{n} \times DEF_{n-i+1})}{VP_n} \qquad (5)$$

Where, $\mathbf{AEF_n}$ is the ***average emission factor*** in year **n**; $\mathbf{NEF_n}$ is the emission factor of new vehicles in year **n**; **DEF** is the emission deterioration level of vehicles which are used in year **n** with **i** age. The number of vehicles in equations 4 and 5 are back-calculated using travel demand projections and making assumptions about modal share and occupancy rates.

The emission factors for SO_2 are calculated independently from the above equations.

$$SO_2 = S \times f \times \frac{64}{32} \qquad (6)$$

Where, $\mathbf{SO_2}$ is the emission factor of $\mathbf{SO_2}$ in **g/l**, **S** is the sulfur content of the fuel in ppm (0.001 for gasoline; 0.003 for diesel), **f** is the density of fuel in **kg/l** (0.75 for gasoline and 0.82 for diesel), and 64 and 32 are the molecular weights of $\mathbf{SO_2}$ and **S** respectively.

44. The regression equation is: Y = 18843631354 + 1407306196 * t - 23226.69781 * Population + 0.163220275 * Gross City Product

chapter SIX

Past trends in energy consumption and pollutant emissions

Historical trends in travel demand, energy consumption and pollutant emission

Photo: Manish Koirala

6.1 Travel demand

The passenger travel demand by motorised modes in the Valley increased from nearly one billion in 1989 to 8.7 billion passenger-km in 2004.[45] In those 15 years, despite a dramatic rise in the number of cars and motorcycles, the shares of each of the major transport modes in the total travel demand remained largely unchanged. In recent years, however, especially after 2001, the share of microbuses seems to be rising. The share of buses and minibuses has decreased slightly and is being met by low-occupancy public transport modes (taxis, three-wheelers and microbuses).

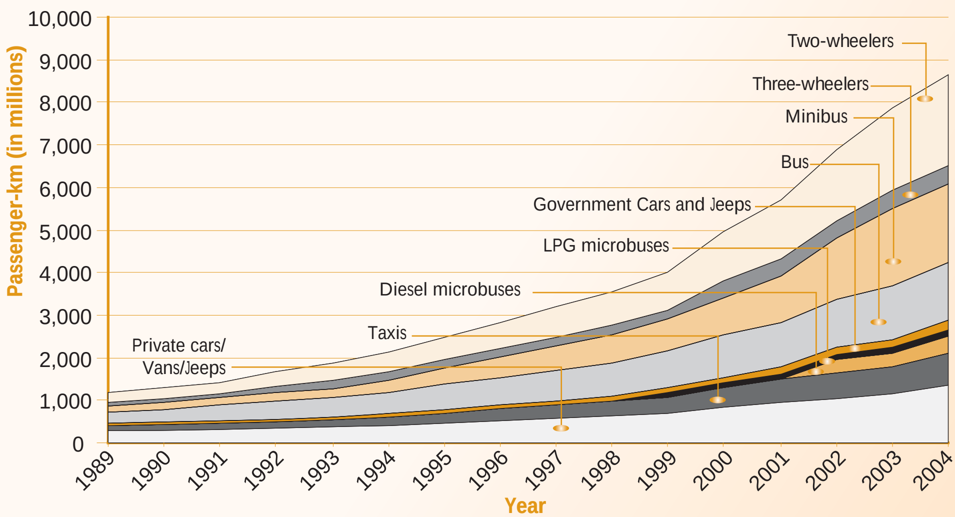


Figure 6.1 **Structure of passenger travel demand in the Valley between 1989 and 2004**

45 It is assumed that there were no changes in either the load factor of the vehicles or in their annual travel distances.

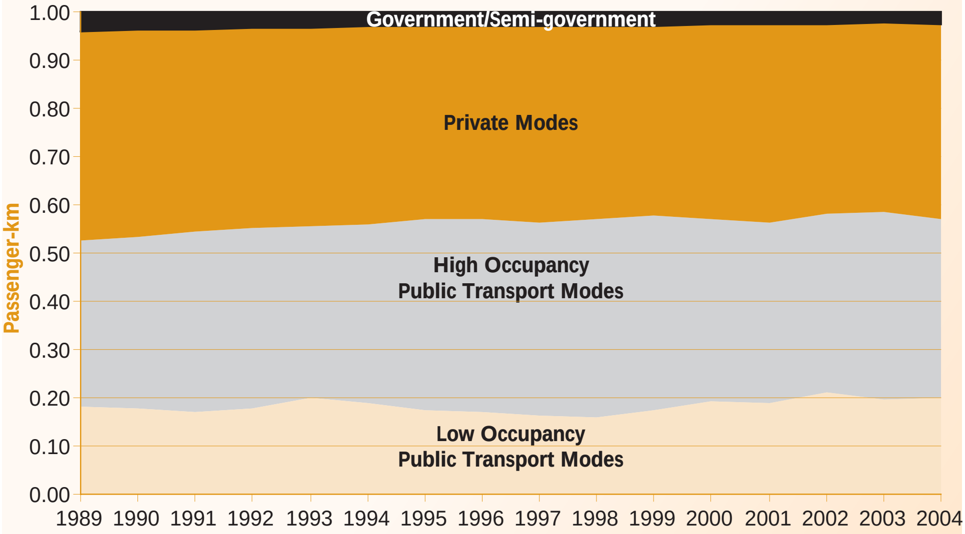


Figure 6.2 Share of travel modes in the Valley between 1989 and 2004

In 2004, public transport modes met about 57% of the total travel demand in the Valley, while private modes, such as cars and motorcycles, met 41%. Motorcycles and private cars constitute 71% and 17% of the total operational vehicles respectively, but they meet about 25% and 16% of the total travel demand. Micro-buses meet about 6% of the total travel demand, whereas buses and minibuses together meet 37% of the total travel demand but make up only 1.4% of the total operational vehicle. Clearly, high-occupancy public transport is very important in the Valley.

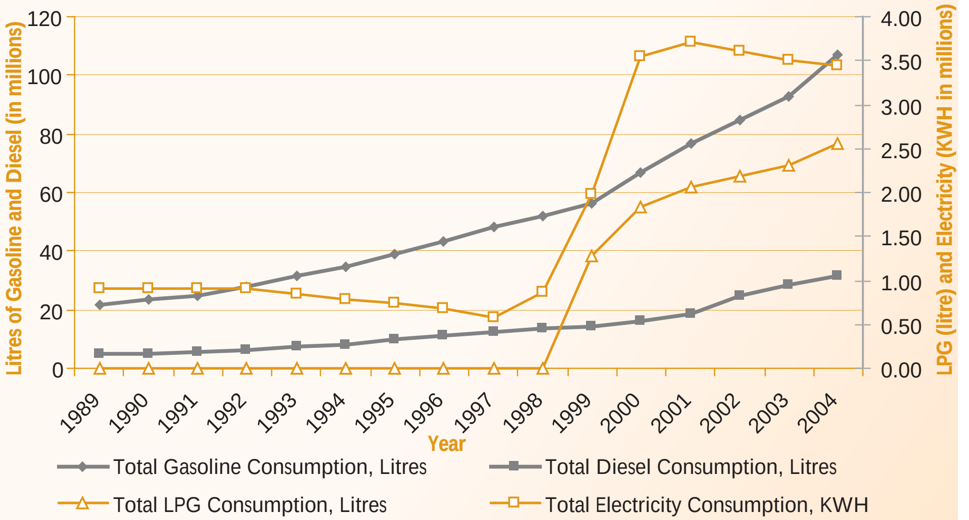
6.2 Energy consumption

The total energy use by passenger transportation in the Valley in 1989 was about 658 thousand GJ; that figure had increased by about seven times in 2004.[46] Gasoline consumption increased by a factor of five and diesel by seven. LPG began to be consumed in the transport sector

46. The estimates assume a 10% deterioration in the average energy efficiency of each vehicle fleet from 1989 to 2004. This figure was increased to 20% after 2004. As it turns out, energy efficiency impacts were nominal, both in terms of the absolute number of vehicles as well as the structure and shares of various travel modes.

in 1999. In 1997 battery-operated electric three-wheelers started to use electricity; their introduction caused electricity consumption to increase, countering the decline in consumption associated with a decrease in the number of operational trolley buses. Though electricity use has stagnated since 2000, LPG usage has continued to rise due to its use in microbuses in addition to three-wheelers. The share of energy consumption of each of the major travel modes has changed little in the last 15 years.

In 2004, gasoline accounted for 75.5% of the total energy demands of passenger transportation, followed by diesel (22.8%), LPG (1.4%) and electricity (0.3%). Private modes—cars and motorcycles—consume about 53% of the total energy consumed and meet 41% of the total travel demand. Low-occupancy public transport modes consume 28% of the total energy used. While buses and minibuses consume as little as 13% of the total energy consumed, they meet 37% of the total travel demand. It is evident that buses and minibuses are more efficient energy consumers than any other mode of transport (see Figure 6.7). Energy intensity is defined as the energy consumed by a single passenger to travel one kilometre. Energy intensity estimates suggest that cars (in-



Note: Electricity is measured in KWH; all other fuels are in given in litres.

Figure 6.3 **Energy consumption by fuel in the Valley (1989-2004)**

cluding taxis) and gasoline-operated three-wheelers are the most energy intensive travel modes in the Valley, while buses and minibuses are the least. In consequence, promoting the latter is key to reducing petroleum imports.

It was impossible to compare energy consumption precisely as there are no published statistics on fuel use in the Valley. The data needed is fuel use by various modes of passenger transportation, which is very difficult to obtain. We chose instead to compare our results with those of past studies. Our findings are presented in Table 6.1.

Our estimated energy demand data tallies closely with past estimates, particularly those of Shrestha and Malla (1993), Shrestha and Malla (1996) and the NOC sales figures cited by Devkota (1992). Our estimates of gasoline consumption are higher than those of Mathur (1993), and Gautam (1994), but details on the methods they used are not available. Our figures may be slightly different from the actual situation as detailed data on the numbers of vehicles by fuel economy and annual distance travelled by fuel type, engine size, and vehicle age are not available and because there are other practical problems such as fuel adulteration. The estimates do, however, provide a tentative picture of past trends for use in analysing future trends and evaluating the implications of different scenarios.

Table 6.1 **Comparison of estimated energy consumption of various modes of passenger transportation**

Source	Year	Gasoline ('000 litres)	Diesel ('000 litres)	Remarks
Shrestha and Malla, 1993		28,015	22,955	Shrestha and Malla, 1993, estimate the entire transport sector, not only passenger transportation. Gasoline consumption is similar to our study, but diesel consumption differs because our study does not include freight transportation, tractors or construction-related vehicles.
Current estimate	1992/93	31,357	7,223	
NOC sales data cited in Devkota, 1992		20,093	70,317	This data is not just for the passenger transport sector; diesel may have included freight transport, industrial and power sector consumption too. Our estimate closely resembles the gasoline estimate as it includes only the transport sector.
Current estimate	1990/91	24,638	5,664	

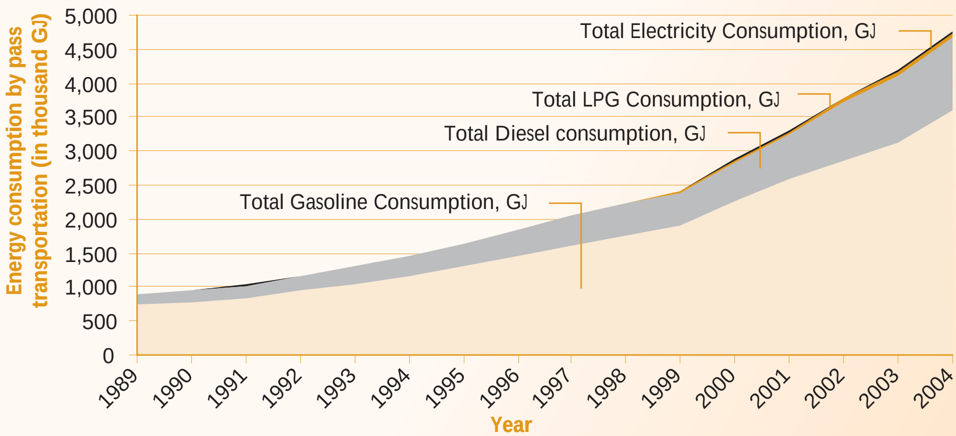


Figure 6.4 **Energy consumption by passenger transportation in the Valley by fuel type**

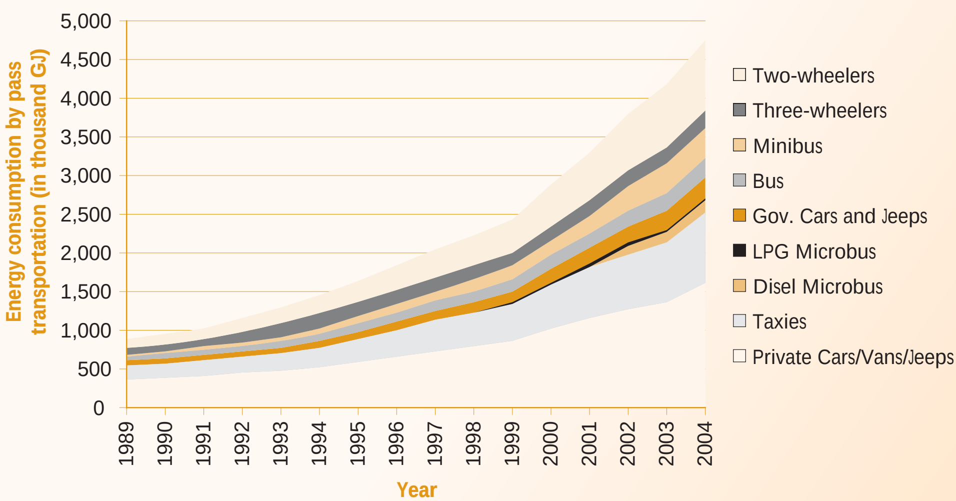


Figure 6.5 **Energy use of passenger transportation in the Valley by vehicle type**

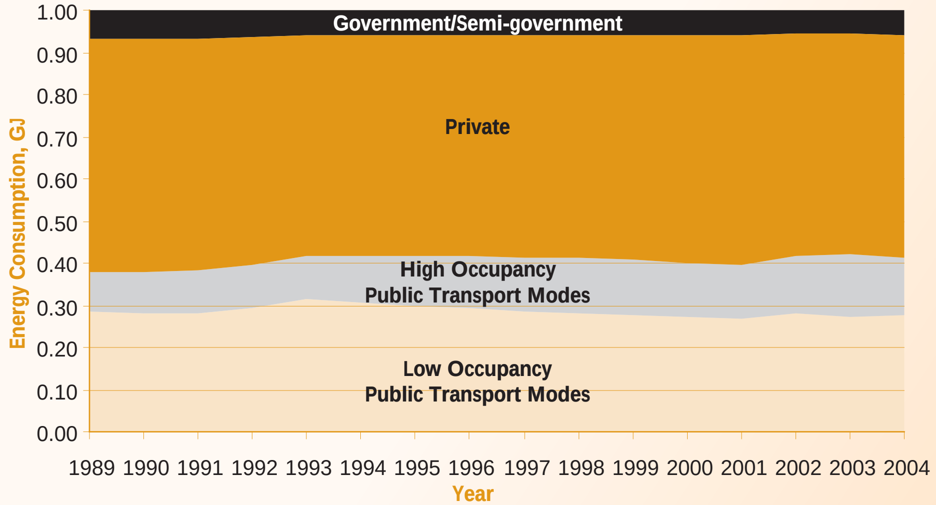


Figure 6.6 **Structure of total energy consumed by passenger transportation in the Valley**

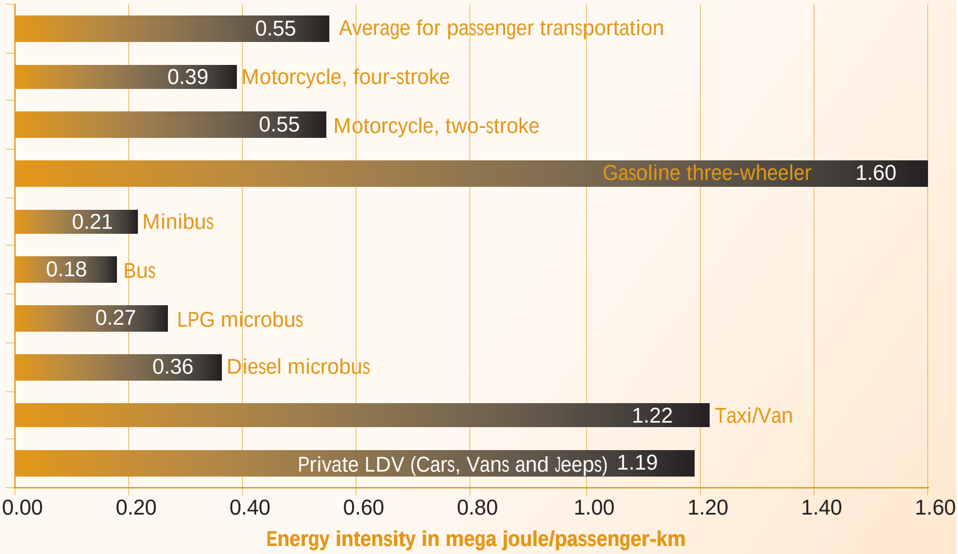


Figure 6.7 **Average energy intensity of various transportation modes in 2004 in the Valley**

6.3 Emission of air pollutants and CO_2

Our analyses suggest that CO, HC, NO_X, SO_2, PM_{10} and CO_2 emissions from passenger transportation in the Valley have increased significantly in the last 15 years: values were four to six times more in 2004 than in 1989 (see Figure 6.8). The volume of PM_{10}, a serious problem in the Valley, has increased by about 4.5 times. Emissions reaches nearly 700 tonnes in 2004. CO_2 has increased by 5.2 times; it reached 537 thousand tonnes in 2004.

The concentration of SO_2, which is not a problem in the Valley, has increased by similar proportions. Levels of SO_2 exceeded, NAAQS in Bhaktapur in recent winter months. The contribution of transportation was nominal, however; the major source was fixed chimney-type brick kilns, which have since been de-registered by the government.

Table 6.2 shows the shares of total emissions of passenger transportation in 2004 by vehicle type, fuel type and travel mode. Private transport modes such as cars, vans, jeeps and motorcycles are responsible for 71% of CO, 63% of HC, 50% of NO_X, 43% of SO_2, 53% of PM_{10} and 55% of CO_2. Low-occupancy public transportation vehicles are the next most polluting; high-occupancy vehicles are the least. Gasoline vehicles account for a very high share of CO_2, CO and HC emissions. Diesel vehicles contribute less CO_2, CO and HC but emit large amounts of NO_x, SO_2 and PM_{10}.

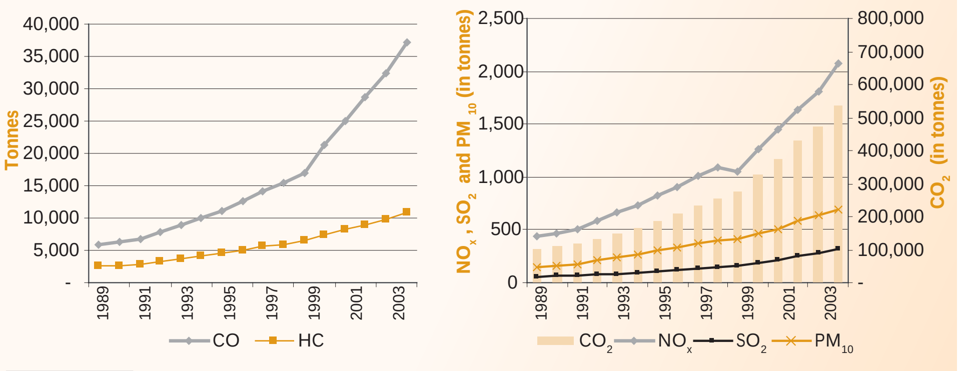


Figure 6.8 Emissions of various air pollutants in the Valley

Table 6.2 Shares of vehicles and modes in the total pollutant emissions in the Valley in 2004

By vehicle type	CO	HC	NO_x	SO_2	PM_{10}	CO_2
By vehicle type						
• Private car/jeep/van	29.6%	33.9%	37.6%	29.9%	20.1%	34.8%
• Motorcycle	3.8%	8.1%	1.0%	2.7%	4.7%	4.4%
• Taxi/van	19.3%	22.0%	22.5%	13.0%	8.9%	20.2%
• Government car/jeep	4.2%	4.8%	6.0%	6.5%	4.3%	5.8%
• Diesel microbus	0.3%	0.4%	2.2%	6.4%	4.2%	2.6%
• LPG microbus	0.2%	0.2%	0.7%	0.0%	0.0%	0.5%
• Three-wheeler	3.8%	8.1%	1.0%	2.7%	4.7%	4.4%
• Bus and minibus	1.2%	1.8%	18.1%	28.7%	24.9%	11.7%
By fuel type						
• Gasoline	97.7%	96.6%	73.8%	51.0%	61.8%	79.2%
• Diesel	2.1%	3.0%	25.0%	49.0%	38.2%	20.0%
• LPG	0.3%	0.4%	1.2%	0.0%	0.0%	0.8%
By travel mode						
• Private	71.1%	62.6%	49.5%	42.8%	53.0%	54.7%
• Low-occupancy public	23.5%	30.7%	26.5%	22.1%	17.8%	27.8%
• High-occupancy public	1.2%	1.8%	18.1%	28.7%	24.9%	11.7%
• Government/semi-government	4.2%	4.8%	6.0%	6.5%	4.3%	5.8%

The contrasts between the shares of various modes for CO_2 and PM_{10} are worth noting since these are the most important emissions in the Valley from the global and the local perspective respectively. Any synergies in or conflicts over local air pollution management and global mitigation of GHGs from passenger transportation are likely to emerge from managing these modes. For example, light-duty cars and vans are the primary targets for CO_2 mitigation, while buses and minibuses are likely targets for PM_{10} control.

The relative importance of various transport modes in the Valley can be further illustrated through emission intensity per passenger-km. The amounts of PM_{10} and CO_2 emitted when a passenger travels one kilometre by various modes are shown in Figure 6.9. Since vehicles are the only means to meet travel demand, a passenger's choice of mode can play a very important role in reducing emissions. The choice to travel one kilometre by low-occupancy public transport instead of private transport can, for example, reduce PM_{10} by 36%, while moving from low-occupancy to high-occupancy public transport reduces CO_2 emissions by 77%. Buses have the lowest emission intensity of all modes. Motorcycles also have a low emission intensity but they take up more space than buses and minibuses do.

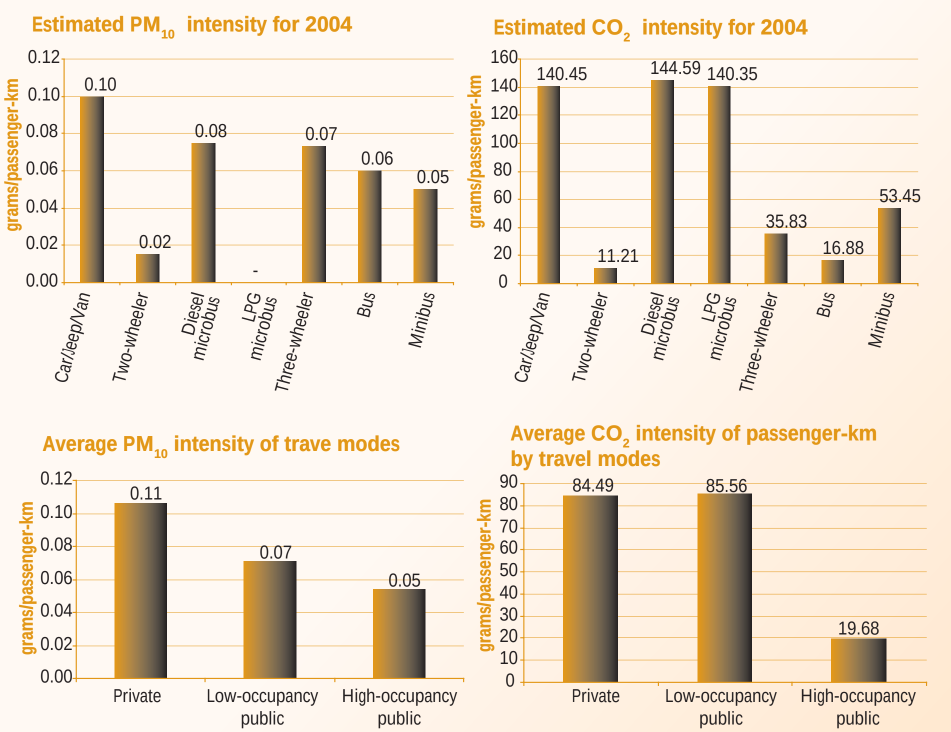


Figure 6.9 **Comparison of emission intensities of various travel modes in grams/passenger-km**

STORE

chapter SEVEN

Future scenarios

7.1 Baseline scenario (BASE)

Imagining the future is a challenging task. One method widely used to foresee the future consists of setting a baseline, usually a business-as-usual scenario, and then evaluating alternative strategies by comparing them to that baseline. This study follows the essence of this strategy but also makes allowances for new initiatives launched by the government and for other expected developments.

7.1.1. Travel demand and vehicles

As discussed in the methodology section, travel demand is obtained from multiple regressions of time, population growth and economic growth. Due to the ongoing political crisis prevailing in the country, there is more certainty about future population growth than about future economic growth. We used the viewpoints of a number of experts on likely economic growth as a major independent variable in our regression analyses. Low, moderate and high estimates were made. Assuming the current problems would continue, we projected a 4% economic growth rate till 2007; after 2007, the low estimate we used is 5%; the moderate, 6.5%; and the high, 8.2%. The variations in travel demand for low, moderate, and high estimates are shown in *Appendix 3*. For further analyses, moderate growth was taken as a reference point for BASE and alternative scenarios. Under moderate growth assumptions, the passenger travel demand of the Valley will be three times more in 2005 (27.2 billion passenger-km) than in 2004 (8.7 billion passenger-km). The expected numbers of vehicles are shown in Figure 7.1[47]. It is expected that there will be twice as many cars and motorcycles in 2025 as there were in 2004. In 2025, the numbers of cars and motorcycles will have quadrupled and tripled, respectively reaching nearly 132 and 390 thousand in 2025.

47 This figure is back-calculated from travel demand in passenger-km assuming the same modal share, vehicle travel demand and load factor as those of 2004. The load factor for private cars gradually declined from 2.6 to 2 by 2004 due to the expected rise in the number of cars. The shares of various modes are assumed to be the same except for small, anticipated changes. This means that the number of each vehicle type will increase proportionately with travel demand.

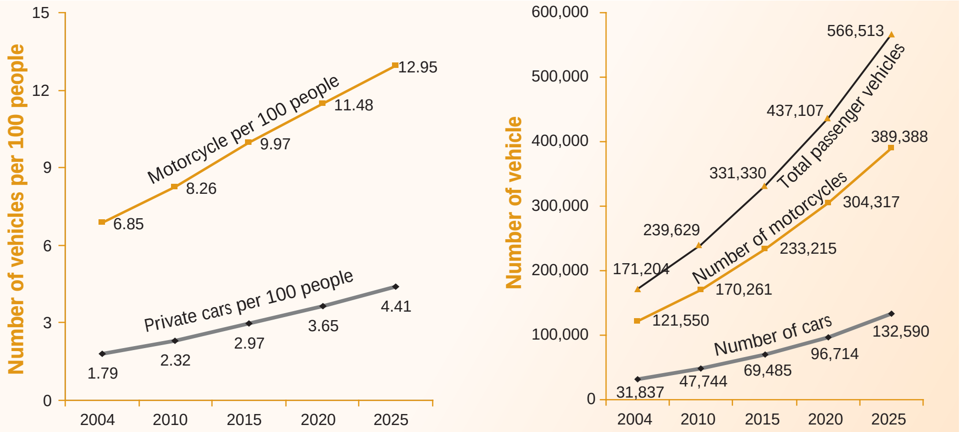


Figure 7.1 **Indicators for the numbers of vehicles in intermediate years in the baseline scenario**

The increase in the number of vehicles, if not complemented with the construction of additional road infrastructure (1,319 km in 2004) and appropriate traffic management, is likely to result in an increase in the level of congestion. In BASE, the number of vehicles per km of road will increase by about three and half times.

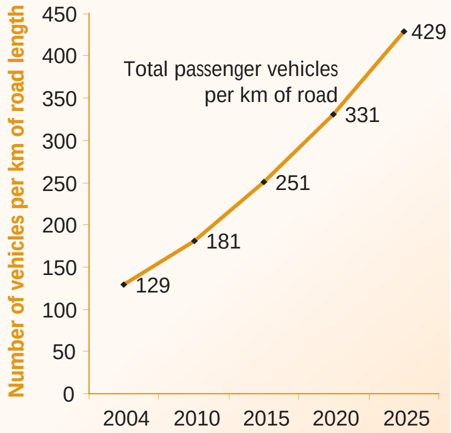


Figure 7.2 **Vehicles per km of road in BASE**

7.1.2 Baseline energy and emissions

The average emission factors and fuel efficiencies of vehicle fleets change over the years due to the introduction of progressively more stringent emission standards and new, fuel-efficient vehicles and to the deterioration of fuel economy and emission performance. This dynamism is incorporated in BASE. The fuel efficiencies of the cars newly introduced in the Valley (the majority of which have 800-1000-cc engines) are about 14-16 km/l. In Japan, the average fuel efficiency of new gasoline vehicles has increased from 12.1 km/l in 1996 to 14.7 km/l in 2003 and 80% of these cars have reached the 2010 fuel efficiency target for the average of all weight classes of vehicles.[48] Expecting future improvements, we assumed a 20% increase in the fuel efficiency of new vehicles by 2025.

Since the government has already implemented EURO-I emission standards for new vehicles, there will be a gradual increase in the penetration level of EURO-I-compliant vehicles into the fleet. However, at the moment there are no plans or discussion of a phase-wise approach to moving to adopt EURO-II or higher levels. The share of vehicles older than 20 years is significant in the total number of operational vehicles and the government has plans to phase out such vehicles. BASE considers this phase-out, assigning an average life of 20 years to four-wheelers and 10 to three-wheelers and motorcycles. Another feature incorporated in BASE is the phase-out of two-stroke three-wheelers, which has already been implemented in the Valley, and the gradual retirement of two-stroke motorcycles, the new registration of which was prohibited in late 2000. Since there are no plans to introduce low-sulfur fuels in the Valley, BASE does not reflect such a change although India's plans to introduce low-sulfur fuel may impact Nepal.

We feel that in the absence of standards in Nepal, Nepal will import the commonly available lower-grade fuel rather than better quality fuels targeted for supply to key Indian metropolises. Based on these assumptions, the estimated average emission factors of priority pollutants and CO_2 in 2025 are shown in Table 7.1.

Table 7.1 Estimated average emission factors of vehicle fleet in 2025 in g/l

	CO	HC	NO_x	SO_x	TSP	PM_{10}	CO_2
Private gasoline vehicle	88.4	3.7	26.5	1.5	2.1	0.6	3984.8
Private diesel vehicle	11.0	5.6	11.8	4.9	10.8	1.8	3440.0
Taxi/van	88.4	3.7	26.5	1.5	2.1	0.6	3984.8
Diesel microbus	15.2	7.6	15.3	4.9	13.8	2.7	3440.0
LPG microbus	47.8	4.5	11.9	0.0	0.0	0.0	1620.0
Government gasoline vehicles	88.4	3.7	26.5	1.5	2.1	0.6	3984.8
Government diesel vehicles	11.0	5.6	11.8	4.9	10.8	1.8	3440.0
Diesel bus	23.5	5.5	35.2	4.9	16.3	11.7	3440.0
Minibus	28.8	5.6	8.6	4.9	12.7	1.8	3440.0
LPG three-wheeler	36.5	15.9	9.6	0.0	0.0	0.0	1620.0

48 Shinsuke Ito, Automobile Divisions of Ministry of Economy, Trade and Industry Japan, Presentation made at International Conference on Transport and Environment, Aichi, Japan, 3 August, 2005.

In BASE, energy use by passenger transport will be 2.2 times greater in 2025 than in 2004. Gasoline will continue to be a major transportation fuel; its share in energy terms will be nearly 74%, followed by diesel (23.5%). The shares of LPG (2.17%) and electricity (0.37%) will be nominal. Categorising fuel consumption by vehicle shows that motorcycles, private vehicles and taxis will account for the majority of energy consumption (76%) while the energy consumption of high-occupancy public travel modes will remain at about 14%. The estimates in this study are lower than those made by the same author (Dhakal 2003a) using a static accounting model which did not take into account improvements in fuel economy or vehicle retirement.

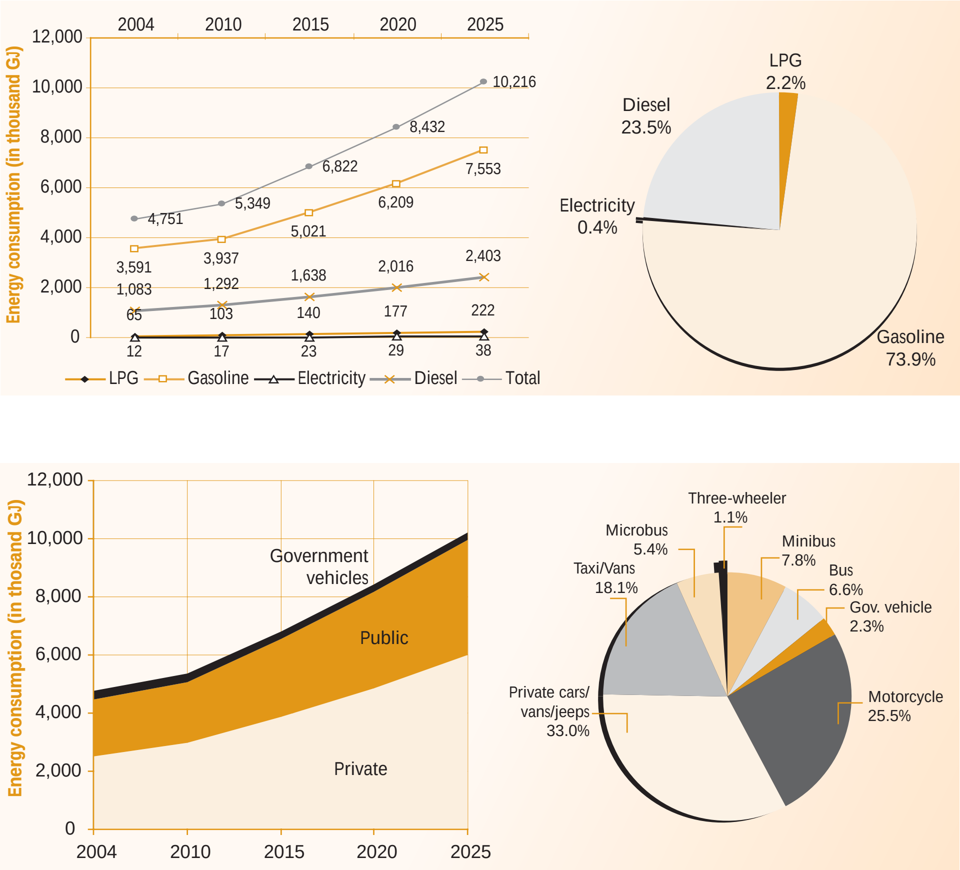


Figure 7.3 **Energy consumption in BASE and the shares of fuel and vehicle types**

Given the rapid rise in energy consumption, it can be expected that emissions from passenger transportation will also increase rapidly. However, due to the greater penetration of EURO-I vehicles, the scrapping of over-20-year-old vehicles and the improving fuel efficiencies of new vehicles, emissions are expected to decrease significantly. The introduction of more EURO-I vehicles and fuel quality improvements will not, however, have any effect on CO_2 emissions, which are estimated to double by 2025 from the 2004 level of 537 million kg. In 2025, 78% of such emissions will come from gasoline use. Private transport modes such as cars, vans, jeeps and motorcycles will account for 61% of total CO_2 emissions though they will meet only 41% of the total passenger travel demand, while high-occupancy public transport modes—buses and minibuses—will account for only 12.7% of CO_2 emission and meet 37.5% of the total passenger travel demand.

Of the priority pollutants, only HC is expected to decrease; all others, except PM_{10} will increase in the first five years. The anomalous reduction of PM_{10} in 2010 is mainly attributable to the following factors:

- Rapid phase-out of 20-year-old vehicles, which exist in significant number in 2004
- Increase in the fuel efficiency of newly-added vehicles
- Greater penetration of EURO-I vehicles into the fleet
- Phase-out of two-stroke three-wheelers in mid-2004 and retirement of two-stroke motorcycles, whose new registration has not been allowed since late 2000, by 2010
- Slower travel demand growth (and slower growth in vehicle numbers) assumed for the first few years beginning in 2004 owing to the expected low rate of economic growth because of the ongoing problems in the country.

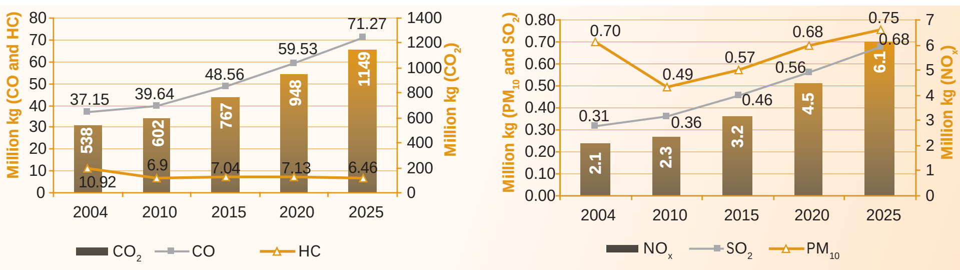


Figure 7.4 Emissions of priority pollutants in BASE

Controlling priority pollutants will continue to challenge decisions-makers for years to come. As PM_{10} concentrations are already higher than healthy limits, it is evident that the existing measures will not be very effective in reducing pollutants since the number of vehicles is increasing rapidly.

7.2 Alternative scenarios—definitions and criteria for evaluation

This study investigated a number of hypothetical alternative policy options derived from a policy dialogue with key stakeholders in the Valley. Not all the options discussed could be evaluated; only the major options, those deemed important and easily assessed using the model developed in this study, were examined. These options are as follows.

- Reducing population stress in the Valley through the decentralisation of economic, political and administrative functions **(activity control)**
- Improving the public transport system and restraining private modes using push-pull strategies **(structural control)**
- Increasing the penetration of electric vehicles into the transport system **(intensity and fuel control)**
- Gradually implementing EURO-II and EURO-III standards in a phase-wise manner along with fuel quality improvements **(intensity and fuel control)**
- Introduction and implementation of a pragmatic "policy package" **(ASIF control)**

These options are evaluated using a number of criteria, as listed below. Although cost is one major criterion, cost comparisons were beyond the scope of this study.

- PM_{10} control
- CO_2 mitigation
- Congestion
- Energy independence

The practicality of some of the options is be questionable, especially the one aimed at restraining population. The extent that others can be implemented is also arguable.

7.2.1 *Population reduction scenario (POP)*

In this scenario, it is assumed that population stress in the Valley will be reduced by decentralising the political, economic and administrative functions of the Valley. Although there is no plan in this direction, the idea has been addressed time and again by all levels of administrative and political establishments. It would also balance regional development in the country. In the absence of existing studies, it was assumed that the average annual population growth rate of 2.54% (as estimated in Development Plan 2020 of Kathmandu Valley published by Kathmandu Valley Town Development Committee in 2002) in BASE would be 2%. This rate of growth would reduce the population by 12% (3 million in BASE) and the population density would decline from 3,343 people per sq. m to 2,943 in 2025. It was also assumed that travel demand would decrease proportionately. Since such measures are long-term, a 6% reduction was projected by 2020 and 12% by 2025.

7.2.2 Public transport scenario (PUBLIC)

It is important to promote public transportation as it can reduce emissions, congestion, and energy use. If this measure is complemented with policies to restrain private transport means such as cars and motorcycles (which take up more road space and are more inefficient on a passenger-km basis), a significant modal shift from private to public transport and from low- to high-occupancy public transport is possible—and desirable. A number of policy measures exist for implementing this so-called push-pull option. Singapore and Shanghai, for example, both have caps on the numbers of vehicles registered annually. Singapore also uses a bidding system called a vehicle quota system, in which owners buy licenses to own vehicles through competitive bidding. It is possible to curb vehicle use through road pricing, fuel taxes, parking control and other measures. Electronic road pricing in Singapore, road pricing in London (five pounds to enter downtown), and tolls on expressways in several cities are examples.

Car-restraining policies may not be popular for a government to adopt but their importance is growing as the numbers of cars and motorcycles are rapidly increasing and the Valley is choked already. A study carried out by DOTM shows that the vehicle-carrying capacity of the existing roads in the Valley has already been exceeded.[49] There was an attempt by the government to halt the new registration of public vehicles for some time. In the future, however, it should be private, not public vehicles that are the target. The assumptions of the PUBLIC scenario follow.

- The share of public transport in the total passenger transport demand will increase progressively over time from 58% in BASE to 70% in PUBLIC in 2025.
- The increase in the share of public transport will come solely from curbing private transportation.
- The load factor of buses and minibuses will decrease from 50 to 40 and 30 to 25 respectively because greater comfort is desirable for promoting a shift from private to public modes.
- The share of high-occupancy vehicles in passenger public transport will increase from 64.7% to 80%. Buses will meet 53% of the travel demand for high-occupancy public transport due to improvements in the quality of service and preferential policies such as exclusive lanes. (This figure is obtained by maintaining the same share of minibuses in total public transport—37.28%—and attributing all additions to buses. This makes the share of buses 42.78% (80-64.7+27.48), or 53% of the high-occupancy share (80%). This means that the share of low-occupancy public transport will decrease gradually over time but that in absolute value it will remain the same as in BASE.

7.2.3 *Electric vehicles scenario (ELECTRIC)*

In this scenario, the role of EVs in the Valley's transportation system is greatly enhanced. Since electricity comes from hydropower plants, electric vehicles are carbondioxide-friendly; besides, they are free of tail-pipe emissions. They also obviate the need to import oil and promote greater dependence on local energy sources. Battery-operated EVs have been in operation in the Valley since 1996; driving conditions (short distances, low speed and acceleration, and flat topography) render the major technical limitations associated with EVs non-problematic. The government has already provided huge tax breaks and waived customs duties on the EV industry and EVs. This sector will also benefit from time-of-day electricity pricing, which will allow it to use off-peak electricity and thereby improve its financial base through CDMs; route preference for trolley buses and three-wheelers; and others incentives.

This scenario consists of the following features:

- Expanding the existing fleet of battery-operated three-wheelers through preferential policies so that all three-wheelers would be battery-operated by 2010.

49 Personal communication with the Technical Director of DOTM on 29 July, 2004.

- Introducing some battery-operated four-wheelers such as India's 800-cc REVA. Government purchase of such vehicles can boost this niche market. It is assumed that 30% of the total travel demand by government gasoline cars will be met by electric cars in 2025.
- Trolley bus services, which are in a state of collapse, will be introduced to the Ring Road, where a study has shown it is feasible to operate them. Favourable government policies will attract private investment. It is assumed that trolley buses will meet 20% of the total bus travel demand by 2025. Based on a recent study by CEMAT Consults Pvt. Ltd., the value for energy consumption used is 1.2 Kw-h/km, which is 0.024 Kw-h/passenger-km with a load factor of 50 and 0.03 Kw-h/km with a load factor of 40 (CEMAT, 1999).

7.2.4 *Phase-wise emission standards scenario (EURO)*

In this scenario, emission standards grow progressively more stringent over time. Nepal adopted EURO-I equivalent emission standards for all new vehicles a few years ago, but it still lacks a plan for moving forward from EURO-I. India's 2002 Auto Fuel Policy provides for Bharat Stage II (equivalent to EURO-II) to be adopted from April 2005 and EURO-III to be adopted from 2010 all over the country. Bharat Stage II was implemented in Delhi, Mumbai, Channai and Kolkata in 2000 and 2001 and in seven additional cities[50] in April 2003. The Auto Fuel Policy proposes to introduce EURO-III equivalent standards in April 2005 and EURO-IV in April 2010 for all private vehicles and for city public service and commercial vehicles in these cities. The "Auto Fuel Policy Report" states that the Indian standard for motorcycles and three-wheelers is already more stringent than that in other regions, but that standards need to be tightened because there are so many vehicles. The European Union has also revised its fuel quality and emission norms every four to five years. Thus, a phase-wise approach is very appropriate.

Nepalese standards cannot surpass Indian standards because of practical realities; however, Nepal can try to catch up with the most advanced emission standards and fuel quality which India uses for its major cities. In this scenario, EURO-II equivalent emission norms will be implemented for new vehicles by 2010 and EURO-III standards will be

50 Bangalore, Pune, Hyderabad, Surat, Ahmedabad, Kanpur, and Agra.

implemented by 2015. It is possible that EURO-II could be introduced before 2010 because Nepal imports all its vehicles and fuels from India and other Third World countries and therefore does not need to worry about automobile industry or petroleum refining-related issues. Nepal will have to match emission standards with relevant fuel quality specifications, especially sulfur content, because of its impact on the emission of PM. In accordance with past research and expert input, BASE uses a sulfur content of 1000 ppm for gasoline and 3000 ppm for diesel. In India, the specifications of the Bureau of Indian Standards (BIS) for 2000 for gasoline and diesel (BIS 2796 and BIS 1460 respectively) are 1000 ppm and 2500 ppm respectively for rural areas and 500 ppm for both in designated areas.[51] For EURO-II and EURO-III norms, the sulfur content of gasoline should not exceed 500 ppm and 150 ppm respectively and that of diesel should not exceed 500 ppm and 350 ppm. For EURO-IV, fuels should be sulfur-free.

7.2.5 *Policy package scenario (PACKAGE)*

In practice, policies and plans for air pollution control from vehicles are formulated and implemented as a package of various measures. One measure alone is usually not very effective as the gains made are often neutralised or overshadowed by their impact ("rebound effect") on other areas. PACKAGE is a set of measures based on the entire ASIF framework. No measure is overly ambitious (or, in different words, they are relatively doable) but all are reasonably comprehensive. PACKAGE has the following features:

- Activity control
  - Reducing the population in the Valley slightly as discussed earlier but at slower rates so that the population of the Valley will be reduced by 10% in 2025.
- Structural adjustment of travel modes (making it essentially multi-modal)
  - Increasing the share of public transport to 65% from the 58% share in BASE. This rise is assumed to come from decreasing the share of private cars and motorcycles in equal proportion. Within public transport, the share of high-occupancy modes is assumed to gradually increase from 64.75% to 80% by 2025 with buses meeting 10% more of the demand than minibuses.

51 Report of the Expert Committee on Auto Fuel Policy, Government of India, August 2002.

  - Increasing the comfort of public transport by gradually reducing occupancy in buses and minibuses from 50 to 40 and 30 to 25 by 2025.
- Energy intensity and fuel improvements[52]
  - Gradually making all three-wheelers electric (not LPG) by 2025.
  - Meeting 5% of the travel demand of buses by trolley buses by 2025.
  - Implementing EURO-II from 2010 and reducing the sulfur content of both gasoline and diesel to 500 ppm.

7.3 Implications of alternative scenarios

In this section, all scenarios are compared to BASE, and their potentials for reducing CO_2, PM_{10}, congestion and energy resources are examined. The major indicators used for comparison are, as described earlier, the amount of "avoided" energy, emissions, number of vehicles, and the substitution of indigenously-produced electricity for petroleum imports.

7.3.1 *Energy consumption reduction potential*

Results show that energy consumption will stay as it is or decrease in the future in all scenarios. Since various measures of each scenario are gradually put in place by 2025, the reduction potential is greater in later years. Analysis shows that PACKAGE can reduce BASE consumption levels by about 1.8 GJ. The next best scenario is PUBLIC, with a 1.3-GJ reduction in 2025. The energy reduction potential of ELECTRIC is nominal because the number of electric trolley buses, electric cars, and battery-operated three-wheelers is so small.

The share of gasoline in total energy use in 2025 is 74% in BASE. In fact, in all alternative scenarios, gasoline will continue to dominate. However, its share decreases to 60% in PUBLIC due to the introduction of more

52 The effects of increasing traffic flow, introducing better inspection and maintenance programmes, and controlling fuel adulteration are important issues discussed during the policy dialogue, but they could not be incorporated because information was limited. However, since the average emission factors for 2004 were borrowed from various sources (and not calculated), reliably incorporating these features would have been difficult anyway. No attempt was made to do so. In the future, if local emission factors for vehicles by size, type and age are established, then reliable average emission factors can be calculated and the effects of speed, I&M programmes and fuel adulteration can be examined.

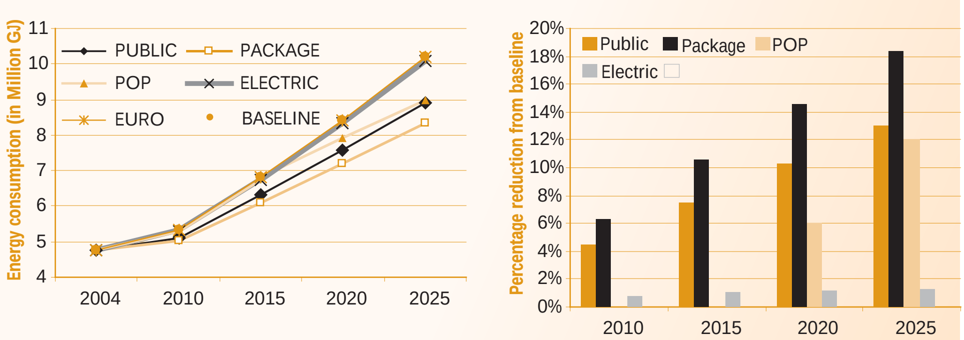


Figure 7.5 **Energy consumption in alternative scenarios and reductions from BASE**

buses and minibuses at the expense of private cars and motorcycles. The share in PACKAGE is about the same 64%. In ELECTRIC, the share of gasoline increases nominally (about 0.5%), as diesel buses are replaced with electric trolley buses.

7.3.2 Share of indigenously produced energy

Increasing the share of indigenously-produced energy (electricity) is important for Nepal. Importing petroleum put pressures on the nation's balance of payments, widens its trade gap, and increases its vulnerability to price fluctuations in the international oil market. The resultant need for making periodic re-adjustments to petroleum product prices in the domestic market is one of the most politically sensitive issues in the country. Despite heavy government subsidies, the Nepal Oil Corporation (NOC) still has a large debt. Electricity, in contrast, is locally produced. If it is not utilised, it spills away. A lot of discussion is going on about the role of electricity in the transportation system, but most is dominated by emission reduction viewpoints. Although the impact of EVs on the total energy system is expected to be small, they can help to alleviate the petroleum problem a little bit and, at the same time, help electric utilities improve their energy utilisation rates.

The amount of electricity used in BASE is nominal (37.6 thousand GJ): its use is limited to about 1,855 three-wheelers in 2025[53]. Electricity use in urban transportation will increase by 354% in ELECTRIC and also increase in PACKAGE. It will, however, decrease nominally in PUBLIC and POP, where the role of low-occupancy

53 BASE is optimistic about battery-operated three-wheelers. This number is obtained from the assumption that the current modal shares of public transportation and three-wheelers will persist in 2005 even if travel demand increases substantially in the future.

public transport will be curtailed and travel demand will be decreased.

The share of electricity in total energy use in BASE remains nominal (0.37%) in 2025. Even in the case of ELECTRIC, where the role of EVs is greatly elevated, the share of electricity in total energy use is merely 1.7%. This share is not that small in absolute numbers, however, in the ELECTRIC scenario, Nepal will have to import 3.9 million litres less diesel, 1.5 million litres less gasoline and 1614 fewer tonnes of LPG in 2025 alone. The savings in costs at current local retail prices is about five million US dollars.[54]

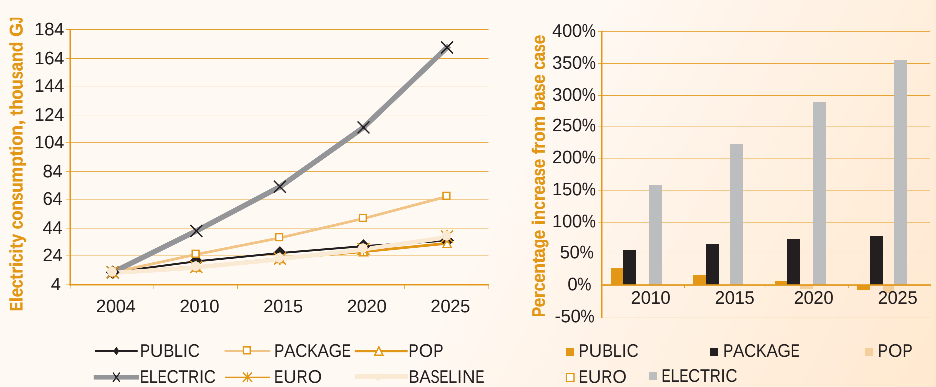


Figure 7.6 **Electricity consumption in alternative scenarios and percentage increase from BASE**

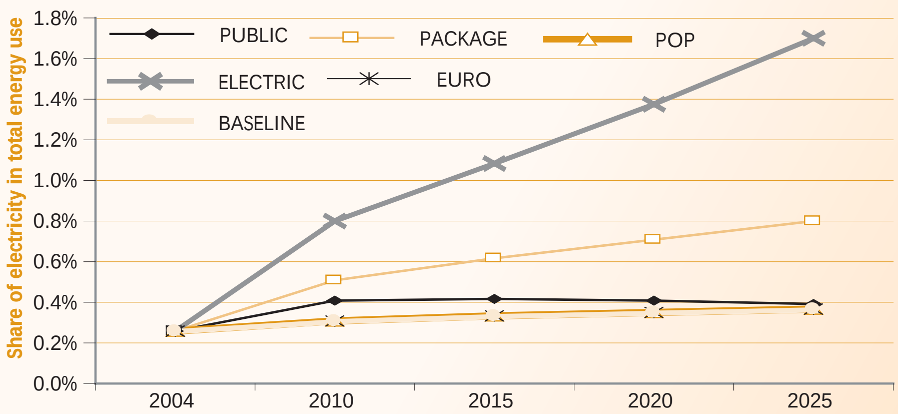


Figure 7.7 **Share of electricity in total energy use by passenger transportation in alternative scenarios**

54 The prices used are diesel, 46 Rs./l; gasoline, 67 Rs./l (as of 20 August, 2005), and Rs. 900 for a 14.2-kg gas cylinder. The exchange rate used was 75 Rs.=1 US$.

7.3.3 CO_2 mitigation potential

Analyses of CO_2 emissions show that PACKAGE has the highest potential to mitigate CO_2 emissions from passenger transportation; it does a 20% better job than BASE. PUBLIC can reduces emissions by 15%. Incorporating EVs will have only a minor impact on CO_2 mitigation as they cater only to a niche market. The average CO_2 intensities of passenger transportation in each alternative scenario are shown in Figure 7.8.

7.3.4 PM_{10} reduction potential

Figure 7.9 shows the PM_{10} reduction potentials of each of the alternative strategies from 2004 to 2025. PACKAGE offers the most effective measures for reducing PM_{10} emissions. Promoting PUBLIC would be very effective in reducing energy consumption and CO_2 emissions but it would increase PM_{10} emissions by 23% in 2025 (due to the increase in the number of buses, whose PM_{10} emissions are higher than those of other modes) if there were no improvements over BASE in the emission performances of vehicles. PACKAGE, which proposes to implement EURO-II equivalent emission norms for vehicles from 2010 onwards, will reduce PM_{10} more than the EURO scenario, in which emission norms alone are greatly strengthened (EURO-II is implemented in 2010 and EURO-III in 2015).

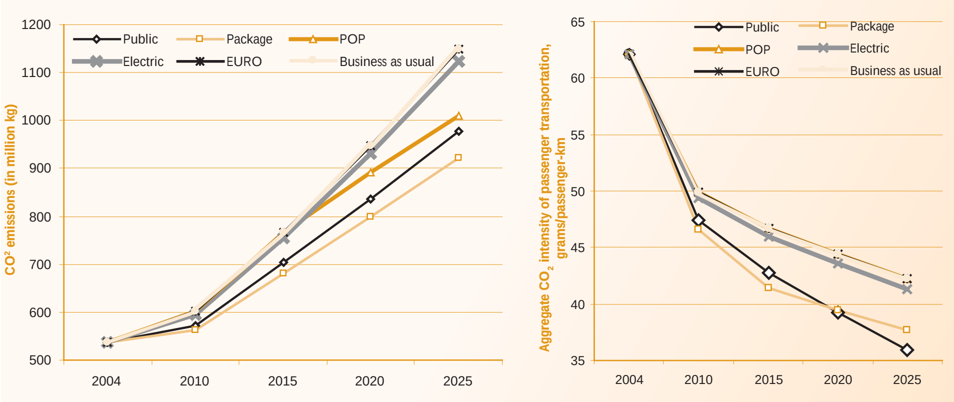


Figure 7.8 CO_2 emissions in alternative scenarios and CO_2 intensity of passenger transportation

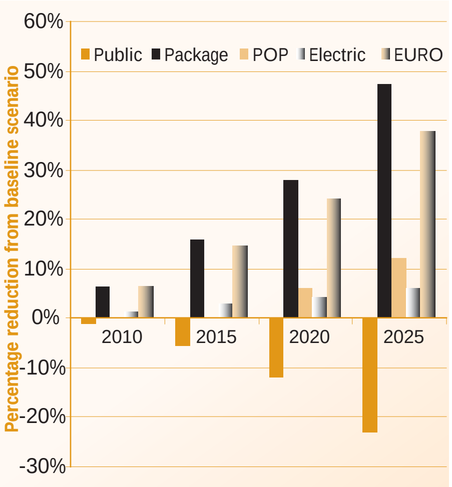


Figure 7.9 PM_{10} reduction potential of alternative scenarios from BASE

7.3.5 Numbers of vehicles reduction potential

The numbers of vehicles will differ according to assumptions made about modal shares and modal shifts and will determine the level of congestion on roads. The total number of vehicles will not decrease in either EURO or ELECTRIC scenarios, which will only affect emission performance and fuel choice, respectively. Promoting PUBLIC will result in the greatest decline in the numbers of vehicles; in 2025 there will be nearly 160,000 fewer vehicles, a 28% greater reduction than in BASE. The decline is largely the result of the reduction in private transport vehicles such as cars and motorcycles as well as the accompanying but smaller increase in the numbers of buses and minibuses. PACKAGE results in the second largest reduction in the number of vehicles (about 145,000 or 26% less than BASE).

Table 7.2 shows the additional numbers of vehicles beyond BASE that each scenario eliminates.

Table 7.2 Number of vehicles reduced from BASE in 2025

	Light-duty vehicles		Low-occupancy public vehicle		High-occupancy public vehicle		Total reduction	
	Car/Van/Jeep	*Motor-cycle*	*Three-wheeler*	*Taxi, Microbus*	*Bus*	*Minibus*	*In number*	*In %*
POP	16,415	46,726	389	3,553	263	634	67,980	12%
PUBLIC	38,807	113,967	221	9,909	(1,850)	(1,217)	159,837	28%
ELECTRIC	0	0	0	0	0	0	0	0%
EURO	0	0	0	0	0	0	0	0%
PACKAGE	34,054	98,770	1,387	12,704	(1,244)	(46)	145,625	26%

Figures in brackets represent increases in the number of vehicles.

The above figures do not show the number of EVs that will operate in each of these alternate scenarios. ELECTRIC, in particular, assumes that large numbers of electric trolley buses will meet 20% of the total bus travel demand in 2025, that EVs will met 30% of the travel demand of government vehicles, and that three-wheelers will be battery-operated. The number of EVs presented in Table 7.3 under each of these scenarios is not unrealistic.

Table 7.3 The number of electric in 2025 in alternative scenarios

	Electric cars	Battery-operated three-wheelers	Electric trolley buses
BASE	0	1,884	0
POP	0	1,658	0
PUBLIC	0	1,755	0
ELECTRIC	948	3,243	438
EURO	0	1,884	0
PACKAGE	0	1,855	171

7.3.6 Priority pollutants reduction potential

Except for PM_{10}, most priority pollutants in the Valley are within the country's NAAQS. Since emissions will increase significantly in the future in BASE, their impacts on pollutant concentrations are expected to increase. In the future, fuel quality is expected to improve and emission norm s to tighten. Thus, emissions on a per vehicle-km basis will probably decrease, but the exact amount will depend on the number, type and size of vehicles and other factors. Such considerations are reflected in the EURO and PACKAGE scenarios. The implications of the alternative scenarios on priority pollutants in the Kathmandu Valley are shown in Table 7.4.

The analyses show that tightening emission standards alone cannot achieve dramatic reductions in pollutants because of the long lives of vehicles. Since the differences between the emission factors of EURO-II and EURO-I vehicles and the pre-EURO-I and EURO-I vehicles already incorporated in BASE are small, EURO's effect is not much greater than that of BASE. However, EURO also reduces the sulfur content of gasoline and diesel to meet EURO-II and EURO-III norms and thus reduces SO_2 emissions 86.7% more than does BASE

Table 7.4 Percentage reduction from BASE of priority pollutants in alternative scenarios

	2010	2015	2020	2025	2010	2015	2020	2025
	CO				HC			
PUBLIC	7.8	14.4	21.0	27.5	7.2	13.4	19.5	25.1
PACKAGE	6.8	14.0	22.3	31.2	4.7	10.4	18.2	22.3
POP	0.0	0.0	6.0	12.0	0.0	0.0	6.0	12.0
ELECTRIC	0.4	0.5	0.5	0.5	0.7	1.0	1.1	1.2
EURO	0.4	1.9	4.2	6.6	0.4	1.5	4.6	2.9
BASE ('000 kg)	37,151	39,642	48,559	59,535	10,919	6,905	7,036	7,134
	SO_2				NO_x			
PUBLIC	1.1	-0.3	-2.4	-5.4	2.0	3.4	5.9	9.1
PACKAGE	62.4	63.7	65.0	66.1	7.8	21.9	38.4	51.1
POP	0.0	0.0	6.0	12.0	0.0	0.0	6.0	12.0
ELECTRIC	1.0	1.7	2.5	3.1	1.7	2.6	3.1	3.3
EURO	67.0	86.7	86.7	86.7	4.4	18.0	36.3	52.0
Baseline scenario value ('000 kg)	314	359	457	564	2,316	3,172	4,483	6,112

in 2025. The EURO scenario also reduces greater amounts of NO_x than other scenarios do. In general, PACKAGE reduces the largest amount of pollutants. PUBLIC can reduce CO and HC emissions but increases SO_2 emissions due to the introduction of a large number of diesel buses and minibuses.

7.3.7 Major outcomes from alternative scenario discussions

- In all scenarios, the increases in travel demand, energy use, and emissions are relatively smaller till 2010 than they are after 2010. This is due to a number of assumptions, including (1) slower economic growth till 2007, which will dampen the growth of travel demand, (2) retirement of two-stroke three-wheelers effective from July 2004, (3) retirement of all vehicles more than 20 years old, and (3) replacement of old vehicles by large numbers of new EURO-I-compliant vehicles. Large amounts of priority pollutants can be reduced by implementing the existing EURO-I emission norms and phasing out older vehicles as long as in-use emission can be checked. The most interesting effect is on PM_{10} emissions, whose levels will drop drastically by 2010, but, in the absence of any further countermeasures, will soon start to rebound.

- An interesting observation about the effectiveness of higher emission norms in the Valley is that the implementation of EURO-II norms from 2010 can reduce large amount of emissions over EURO-I norms, but that any additional gains in emission reduction made by introducing EURO-III in 2015 would be nominal in 2025. This difference is highlighted by comparing the EURO and PACKAGE scenarios.
- The tightening of emission standards in EURO is very effective in reducing concentrations of SO_2, PM_{10} and NO_x but ineffective in reducing CO_2 emissions or energy use, promoting the utilisation of indigenous energy sources and reducing congestion by reducing the number of vehicles on streets. Tightening emission standards is a necessary but not sufficient measure for the Valley.
- The large-scale introduction of a bus system as a means to improve public transportation will reduce large numbers of cars, motorcycles, and low-occupancy public transport modes and help to reduce congestion and energy consumption. However, if no progressive emission standards are introduced, PUBLIC will result in increases in the levels of PM_{10} and SO_2. PM_{10} is particularly undesirable as the high concentration of PM_{10} is already one of the biggest problems in the Valley.

For the short-term—the next five years—the analyses show that the combination of existing and planned measures for the Valley will be effective in reducing emissions if they are properly implemented and if in-use emission control is strictly enforced. Although the number of vehicles will continue to grow, the rate of growth will slow. For the next five to 20 years a number of measures are necessary. We emphasise that no single measure will be able to meet the multiple objectives that the public dialogue identified. A balanced approach is needed to address pollution, public transport, congestion, and energy security, and, if possible, to contribute to the global cause of reducing CO_2 emissions.

The PACKAGE scenario formulated in this study addresses a number of factors in the ASIF framework which hold promise for the Valley. It consists of a package of measures with small improvements in transport activity control, a modal shift, decreases in energy consumption and emissions, and improvements in fuel quality. This comprehensive package seems to be the best option for meeting the various objectives of the Valley, as shown in Table 7.5. It is also more administratively and politically feasible than a scenario which seeks to make major interventions in just one or two areas.

Table 7.5 Performance of various scenarios over BASE in 2025

Scenario	CO_2 emission reduction, %	PM_{10} emission reduction, %	Car and motorcycle reduction, number	Total energy consumption reduction, %	Cumulative CO_2 reduction 2005-2025 million t	Increase in electricity use in 2025, thousand Kw-h	Total electric vehicles, number in 2025
POP	12	12	63,141	12	0.71	1,254	1,658
PUBLIC	15	(23)	152,774	13	1.54	(715)	1,755
ELECTRIC	2.1	6.2	0	1.2	0.24	37,092	4,629
EURO	0	37.7	0	0	0	0	1,884
PACKAGE	20	47.2	132,824	18.3	2.04	8,002	2,026

chapter EIGHT

Removing barriers to the implementation of the scenarios

Photo: Manish Koirala

8.1 Synergies between and conflicts over air pollution and CO_2 mitigation

The scientific community recognises that reducing GHG emissions from the rapidly rising transport sector is essential for the future of Asia, especially considering the large volumes of GHGs emitted by India and China. Given that the developed nations of Annex-I[55] are still struggling to reduce GHG emissions, it is hardly expected that Asians cities will be able to cope in the near future. Certain general challenges for the policy-makers of Asian cities in terms of mitigating GHG emissions from urban transportation include building awareness, identifying resource constraints, and promoting scientifically sound research (IGES, 2004). Although there are no precise groups under which Asian cities can be classed, the following three categories highlight priorities and differences that affect emission policies (see Dhakal and Schipper, 2005).

Developing cities: In these cities, the capacity and authority of local policy-makers are weak, resources are scarce, institutions for urban environmental management are undeveloped, policy enforcement mechanisms are feeble, the involvement of stakeholders is minimal, local pollution issues are the main priority, and problems are often intricately interwoven with poverty issues. A number of cities of South Asia and Southeast Asia, such as Dhaka, Kathmandu, Delhi, Calcutta, and Karachi, fit in this category.

Rapidly developing/industrialising cities: In these cities, the capacity of local policy-makers is improving rapidly, resources are scarce but starting to build up locally, and local institutions are being strengthened. Local issues dominate attention but there is growing awareness of the need to consider newly emerging issues such as global warming. Beijing, Shanghai, and Bangkok belong in this category.

Relatively developed/mature cities: In these cities, conditions are better

55 Belonging to Annex I of the United Nations Framework Convention on Climate Change

than they are in the rest of Asia and local governments are under growing pressure to tackle emerging global environmental issues. The standards of these cities are much higher than those in other cities, but they still struggle to control fine PM and ozone. Cities in Northeast Asia, such as those in Japan and South Korea, are examples.

Policy-makers in developing countries still view GHG mitigation as a diversion from their immediate needs and as a barrier to economic growth. The keys to changing this perception are (1) to link GHG mitigation with clear local benefits such as air pollution and energy savings and (2) to facilitate the transfer of financial resources from developed countries to developing countries for local benefits (Kojima and Lovei, 2001). Developing an integrated policy response to air pollution, energy efficiency and GHG emission reduction is not an easy task though energy efficiency improvement can provide an easy entry point (OECD, 1995). In developed countries, while the rate of motorisation is unprecedented, improvements in the fuel economy of vehicles have played a major role in decreasing air pollution (Kojima and Lovei, 2001). Another area with the potential for integrated response is mitigating traffic congestion, which increases vehicle speeds, potentially reduces emissions, and improves fuel efficiency. Some studies report that increasing traffic speeds from between 10 and 20 km/h can cut CO_2 emissions by 40% (Kojima and Lovei, 2001). While optimism does exist, other studies from Mexico and Chile show that locally favoured options do not always match GHG mitigation objectives and that global benefits are limited (Eskeland and Xie, 1998). In Tokyo, vehicle growth has nearly stagnated, vehicle mileage travel is largely unchanged, and fuel efficiency in all sizes of vehicles continues to improve. Still, CO_2 emissions from transport are on the rise, primarily due to a behavioural factor: car owners in Tokyo are gradually shifting towards driving bigger cars. The levels of NO_x and SPM emissions remain a major issue in Tokyo; interventions in GHG-friendly diesel vehicles are needed (Dhakal, 2003b). In many developing countries in Asia, a technology fix at the tail-pipe is a common solution to air pollution problems, but this measure does nothing to reduce GHG emissions.

The exact impacts of the measures best suited for mitigating priority air pollutants on reducing GHG emissions have not been thoroughly studied and the levels of their potential synergy and conflict are largely unexplored in terms of ground realities. What, for example, are the effects of various PM_{10} mitigation measures and associated policies on GHGs? Answering this question becomes more complicated when the local solution proposed is to change the entire fuel cycle, fuel type or vehicle technology, changes which require first evaluating global benefits over the entire life cycle. The first steps in implementing any integrated measures (apart from fuel efficiency and average vehicle speed improvements) is to identify reasonable, synergistic measures, to encourage policy-makers in developing countries to implement them, and to provide financial mechanisms such as CDMs and other multilateral and bilateral means. Change cannot be achieved without the strong desire of international institutions and developed countries to get involved in the local environmental problems of developing countries.

Kathmandu falls in the first class of cities, where strategies that are meant exclusively for CO_2 mitigation are neither practical nor feasible. For this reason, this study opted for a number of locally possible measures and evaluated their implications against a number of locally important indicators, including CO_2 emissions. The scenario analyses suggested that no single measure could fully meet the local expectations of the city. Instead, a package of measures addressing a range of issues is most suitable. The PACKAGE scenario offers the best solution to the Valley for addressing locally important issues such as reducing PM_{10} emissions, improving public transport and increasing the share of electricity. It is interesting to note that PACKAGE also offers the best way to mitigate CO_2 emissions. In short, there is a synergy between the air pollution reduction measures and CO_2 mitigation measures suitable for the Valley. Conflict could arise, though, from the fact that not all individually-implemented air pollution reduction measures, especially ones that fix emissions at the tail-pipe only, can reduce CO_2 emissions.

8.2 Policies and implementation gaps: The ASIF approach

There are distinct gaps in the countermeasures currently being implemented in the Valley, as described in Section 4.4. The focus of air pollution control measures revolves around vehicle tail-pipes and does not recognise the activities and structure (AS) part of the solution. Interestingly, public transportation vehicles have often been blamed during policy discussions. In response, the government did not allow new public transport vehicles to register for a brief period a few years ago, though it placed no restrictions on private vehicles.

While urban planning-related issues such as containment, land pooling and mixed land-use have long been advocated in the Valley, such measures have not been implemented of the fact that travel demand reduction-related measures could not be incorporated well into these analyses due to a number of technical problems is a weakness of the study. Table 8.1 shows the measures used in PACKAGE, the most desirable scenario, and the challenges associated with implementing each.

Table 8.1 | ASIF portrayal of the PACKAGE scenario and the challenge to its implementation

Component	Approach	Associated challenges
A Activities	Reducing travel demand by reducing the rate of in-migration to the Valley	• Reducing in-migration through regionally balanced national development and decentralisation of the political, administrative and economic functions of the Valley. • Increasing political commitment to implement urban development plans. • Fostering comprehensive planning by overcoming the fragmented jurisdiction of the Valley by many municipalities and VDCs. • Calming downtown traffic by improving roads, intersections and link roads.
Structure	Increasing the share of public transport and reducing that of cars and motorcycles	• Reforming the bus system and improving its reliability and quality • Managing parking and introducing other ways (fiscal, economic, physical) to control the numbers of cars and motorcycles • Improving the robustness of I&M programmes
Intensities	Phasing out vehicles older than 20 years	• Implementing measures in spite of fierce opposition from concerned stakeholders
Fuel	Implementing progressive emission standards and promoting the use of more battery-operated three-wheelers and trolley buses	• Mobilising government agencies to implement new emission standards • Finding the right incentives for the electric vehicle industry • Reviving and expanding the trolley bus system

8.3 The nature of short- and long-term measures: The results of the policy dialogue

A number of solutions to the barriers to reducing transport-energy-emission problems in the Valley have been proposed. These proposals, as described below, are essentially those addressed by PACKAGE but are not limited to that scenario alone. They address the challenges from both a short- and a long-term perspective. These prescriptions are not a direct result of this study's quantitative analyses but were obtained through a focused two-day policy dialogue (essentially a brainstorming exercise with relevant stakeholders). These outcomes are useful for presenting barriers and possible solutions in a practical way. The participants in this dialogue included various stakeholders, as indicated below.

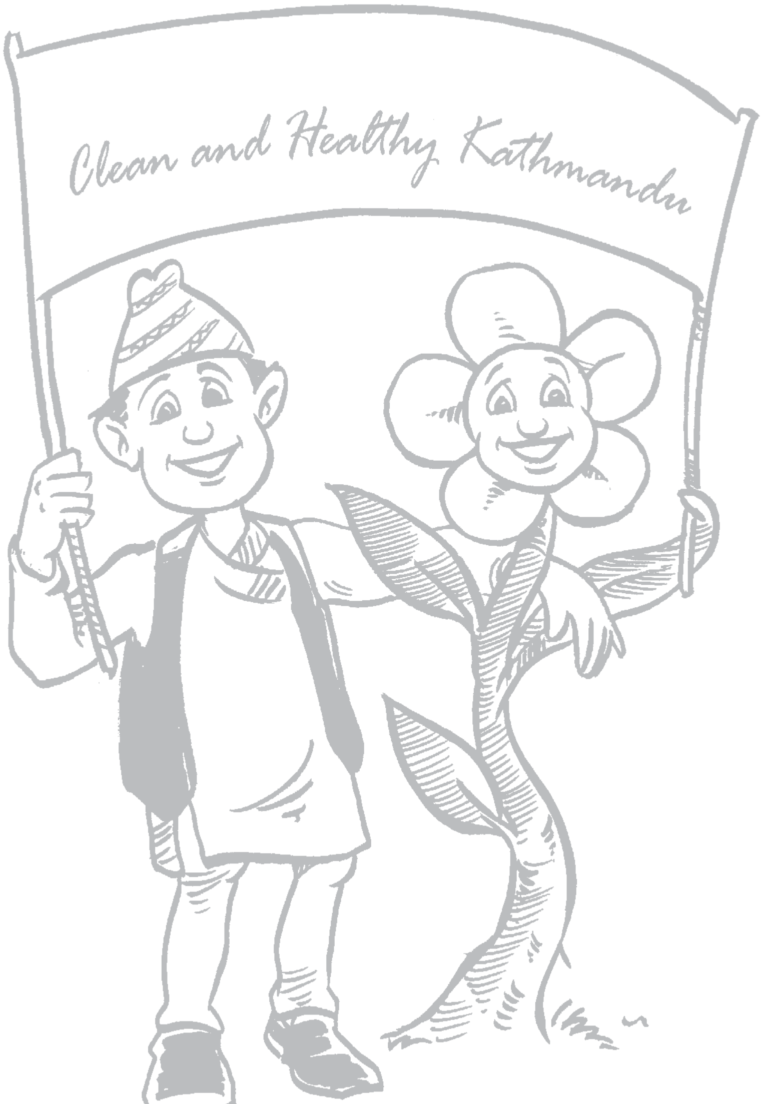
- Locally-recognised experts from academic and non-academic institutions such as the Institute of Engineering as well as the air quality management advisors of donor-assisted projects.
- International experts from the Asian Institute of Technology; Clean Air Resources, the Netherlands; and IGES, Japan.
- Government decision-makers (including MOPE, DOTM, KVTPO, NOC, and the National Planning Commission)
- Municipal government representatives such as those from the Kathmandu Metropolitan Corporation and others
- Transport entrepreneurs such as the Federation of Nepal Chamber of Commence and Industry and representatives of the EV industry
- Local environmental NGOs such as Clean Energy Nepal and Winrock International/Nepal
- Media persons (such as the Nepal Forum for Environmental Journalists and other media outlets)
- Donor community representatives such as the EU Delegation Office and Japan International Cooperation Agency (JICA).

A summary of the discussion is presented below. It is divided into three types of issues: (a) regulatory, such as standards and legislation and their enforcement, (b) urban and transportation planning and management, and (c) technological aspects such as fuel quality, vehicle technology and alternative fuels.

Table 8.2 Results of the policy dialogue with stakeholders: short- and long-term solutions to transport-energy-environment problems

Area	Short-term actions	Long-term actions
Standards, legislations and their enforcement	• Developing a standard emission testing procedure by the MOPE and the DOTM. • Setting fuel quality standards and making them public by allowing people to check the quality of fuel at Nepal Bureau of Standards and Metrology (NBSM)-accredited laboratories. • Regular checking of fuel quality at gas stations and publishing results in the media so that consumers can make good decisions even if government enforcement mechanisms do not penalise culprits. • Establishing penalties for emission violators which are higher than the cost of making repairs in order to comply with emissions. The MOPE can formulate such legislation. • Finding appropriate ways, such as odd-even license numbers, to curb the usage of private cars and motorcycles. • Enforcing emission standards for in-use vehicles by regular testing, road-side testing, calling smoky vehicles for emission tests and prohibiting smoky vehicles in certain places. This can be done by the DOTM, the KVTPO, or by private workshops. The current efforts are not sufficient. • The frequency of testing should be increased for heavy diesel vehicles, older vehicles and all commercial vehicles. • Increasing the cost of testing so that it recovers the actual cost and there by reduces the financial burden on the government. Coordinating the efforts of the two key enforcement authorities, the DOTM and the KVTPO, is necessary.	• Developing progressive emission standards for new vehicles using a step-by-step approach and a clear road map • Improving fuel quality by coordinating between the MOPE and other line ministries and involving the private sector in fuel supply. • Procuring the best quality of fuel that India supplies to its major metropolitan cities. • Increasing awareness about the emission of vehicles and its likely effects by the MOPE with the support from NGOs and the media.
Urban and transportation planning and management	• Improving the transport policy formulation process. A separate, detailed transportation policy that deals with the long- and short-term needs to be made with the participation of various stakeholders. • Focusing the Valley's short-term transport policy on pollution reduction from vehicles, improving the performance of public transportation, and traffic management by developing bus lanes, introducing proper one-way management and reducing encroachment on the transport infrastructure. • Pooling land and planning an Outer Ring Road. • Implementing JICA study's recommendations on widening roads and improving major intersections. • Reducing peak-hour traffic by staggering the official hours of offices, schools, and other trip-generating activities. • Improving the reliability and quality of public transportation with clear timetables, comfort, punctuality and route maps. • Prohibiting large and wide-body vehicles from travelling on narrow routes. • Managing pedestrians by creating awareness about their duties and rights. • Promoting electric vehicles in high population density, tourist and heritage places. • Developing an Inner Ring Road within Kathmandu Valley and extending and widening the Ring Road to make it faster.	• Relocating major institutions outside Kathmandu in a planned fashion in order to reduce in-migration to Kathmandu Valley. • Constructing an Outer Ring Road round the Kathmandu Valley to reduce pressure on core areas • Developing appropriate forms of MRT between the city cores of Kathmandu, Kirtipur and Bhaktapur • Developing a comprehensive transport management system plan and following up on it consistently • Promoting a non-motorised transportation system with clear policies and incentives • Imposing progressively increasing annual registration fees on vehicles based on age, size, and efficiency

Area	Short-term actions	Long-term actions
Technological aspect such as fuel quality, vehicle technology and alternative fuels	• Strengthening the fuel quality control mechanisms of the NOC • Studying the potential of alternative fuels such as CNG, LPG, and ethanol-blended gasoline • Setting the price of fuel according to international oil price fluctuations by reviewing prices every two weeks, as is being done in India • Enhancing R&D in electric vehicles both in terms of policy and technical research. Efforts are needed to reduce the cost by lowering the price of off-peak electricity (which would not affect government revenues as it is currently wasted). This could be done through time-of-day metering. A number of ways to enhance the niche market of battery-operated vehicles is possible, including the introduction of airport shuttles and school buses to make a wider range. • Introducing trolley buses to the Ring Road and expanding the current service route	• Ending the monopoly of NOC over fuel supply and distribution and involving the private sector so that the market can determine the quality and price of fuel • Updating to EURO-I standards to make sure that Nepal follows standards similar to those in major Indian cities. In the long term, Nepal should adopt the highest standards that India adopts.


Clean and Healthy Kathmandu

chapter NINE

Conclusions and recommendations

Photo: Dilip K. Munankarmi

Due to rapid rates of motorisation, urban transport is gradually determining the state of air pollution in many Asian cities. Not surprisingly, combating air pollution from vehicles is a top priority of urban centres. CO_2 mitigation efforts in Asia will have to confront the issues of local priorities, resource constraints and inadequate awareness. Studies show that the best entry point for CO_2 mitigation in developing countries is to integrate it into urban development and local environmental priorities and to strengthen international financial mechanisms such as CDM and other multilateral and bilateral sources which facilitate cities in choosing CO_2-friendly local actions. Improving the energy performance of the transport sector is one entry point with multiple benefits. A modal shift from private to public transport is another beginning; it can reduce the level of congestion, air pollutants, CO_2 emission and energy use. Restraining motorised travel demand and utilising renewable energy are other measures with multi-dimensional benefits. Not all air pollution or locally prioritised measures in the transport sector have multiple benefits. Tail-pipe measures are particularly limited. Other measures reduce air pollutants but either do not impact or actually increase CO_2 emissions. Each city has its own characteristics, synergies and conflicts with respect to CO_2 and air pollutant mitigation.

This study aimed to study the nature of air pollutant emission, energy use and CO_2 emission in the Kathmandu Valley, to look at past and future scenarios, and to identify plausible synergistic mitigation measures. The study developed an inventory of indicators for air pollutants, energy use and CO_2 emission by passenger transportation in the Kathmandu Valley for the past and projected them into the future using a bottom-up, dynamic accounting model and a scenario approach. The study then held a policy dialogue with relevant stakeholders to identify local priorities (PM_{10}, congestion and energy use, in this case), past achievements, and potential present and future avenues for policy interventions.

Using the outcomes of the dialogue, available data, and the model, a number of hypothetical scenarios that reflected local conditions and potential intervention avenues were formulated. These were then evaluated using a few relevant indicators for local concerns (PM_{10} reduction, the number of vehicles [a proxy for congestion], energy saving, and utilisation of indigenous energy resources) and for the global context (CO_2 mitigation).

The results of this study indicate that in 2004 Kathmandu Valley's motorised travel demand had increased 8.7-fold from nearly one billion passenger-km in 1989 and that it would further increase to 27 billion by 2025. The share of public and private transport modes, however, had changed little in those five years; public transport still meets a little over 50% of demand. This means that the number of vehicles operating will increase to half a million from the existing 170 thousand. By 2025, the rates of ownership of cars and motorcycles are both expected to double and the number of vehicles per km of road length to triple. Energy consumption by passenger transportation in the Valley has also increased; in 2004, transport consumed seven times more than the 658 thousand GJ it used in 1989. Projections show that it will increase only about 2.2 times by 2025 as more fuel-efficient vehicles penetrate the transportation system. As before, gasoline is expected to dominate transportation fuel; electricity and LPG will play nominal roles.

Currently, private cars and motorcycles, which make up 71% of the number of operational vehicles, meet 41% of travel demand and consume 53% of the total energy. High-occupancy public transport, i.e. buses and minibuses, on the other hand, make up only 1.4% of the number of vehicles but meet 37% of travel demand and consume only 13% of the total energy. Using the amount of energy consumed to travel one passenger-km by bus as a point of reference, the amount is double for motorcycles and microbuses, 6.5 times for private cars, and 20% more for minibuses. Public beats private transport in terms of its ability to reduce vehicle numbers, save energy and meet large travel demands. Passengers' choice of travel modes, thus, has an important role in determining levels of emissions.

The data from six air quality monitoring stations in the Valley show that most of the priority pollutants are within the limit of NAAQS, PM_{10}, however, is two times NAAQS in winter months. It is estimated that PM_{10} emissions from passenger transportation increased by 4.5 times between 1989 and 2004. The emission of PM_{10} from passenger transportation is expected to decrease in the next five years, if emission from in-use vehicles does not increase and it current modal shares persist. The decrease can be attributed to several factors: greater penetration of EURO-I vehicles into the fleet, expected improvements in the fuel efficiencies of new vehicles, the phasing out of vehicles older than 20 years, the banning of two-stroke three-wheelers and motorcycles, and slower growth in travel demand in the next three or four years due to the expected slowing of economic growth. Levels will soon increase again, though, unless standards are tightened, because of the deterioration in the emission performance of newly introduced EURO-I-compliant vehicles and because of the rise in the number of total vehicles. PM_{10} emission will likely catch up to and even exceed the present level by 2025.

Although other priority air pollutants are within Nepal's NAAQS, these standards may need to be made more stringent in the future. Level of CO, NO_x and SO_2 are expected to increase. NO_x has been particularly difficult to control in the cities of a number of industrialised countries, including Japan. Although this study has not been able to show how a rise in the emissions of priority pollutants will affect air quality in the future, caution is necessary and emissions must be decreased.

Because of Nepal's low per capita vehicle ownership rates, the volume of CO_2 emissions from passenger transportation in the Valley is lower than that in cities in developed regions of the world. This rate has however, increased 5.2 times since 1989 due to the rising number of private cars and motorcycles. It is estimated that the volume will double again by 2025 from 537 thousand tonnes in 2004. The majority of CO_2 emissions will come from gasoline use. In particular, private cars and motorcycles emit four times more CO_2 in grams per passenger-km than buses and minibuses do. Interestingly, the emission of CO_2 from microbuses is as bad as that from private cars. Shifting from private transport to low-occupancy public modes which run on petroleum products (gasoline, diesel or LPG) clearly does not help to reduce CO_2 emissions. The change would, however, reduce PM_{10} emissions noticeably.

Past and present policy initiatives and countermeasures are not comprehensive as most focus on tail-pipe emissions. This study emphasised the need to develop a comprehensive policy accompanied by a set of practical countermeasures covering all major components of the ASIF framework. It re-emphasises that small, pro-active and upstream countermeasures such as managing travel demand and fostering a modal shift towards public transportation will reduce a large amount of the pressure to implement downstream countermeasures such as tail-pipe emission control.

The five alternative scenarios formulated in this study are based on a policy dialogue and incorporate a number of short- and long-term countermeasures. These scenarios focus on (1) reducing travel demand by dampening the population influx, (2) promoting public transportation over private cars and motorcycles (3) encouraging large-scale utilisation of EVs, (4) tightening emission standards gradually, and (5) implementing a package of measures with small interventions to address various ASIF components.

The study shows that each scenario has certain advantages but that none alone would be able to meet the major objectives of the city (controlling PM_{10}, saving energy, using more indigenously-produced energy sources, reducing the number of vehicles to mitigate congestion, and reducing CO_2 emissions). It shows that reducing travel demand by a significant amount may be able to address all objectives but that this is a long-term measure (which will have no effect in the short-term) and that its feasibility is questionable due to the past failures of various urban development plans. A shift of 15% of the modal share to buses and minibuses, for example, is likely to increase PM_{10} by 23% in 2025. The introduction of EVs on a large-scale, in contrast, would not reduce congestion and would reduce PM_{10} and CO_2 only nominally. Implementing progressively more stringent emission standards to EURO-III in 2015 will not help to reduce congestion, save energy, or utilise more electricity. Some of the key ideas that emerged from the scenario analyses follow.

- Implementing EURO-II norms starting in 2010 can reduce emissions substantially, but the benefits in emission reduction gained by 2025 through introducing EURO-III for new vehicles in 2015 would be nominal.
- Tightening EURO emission standards will very effectively

reduce SO_2, PM_{10} and NO_x, but it is not a sufficient step for the Valley.

- The large-scale introduction of a bus system as a means to improve public transportation will reduce large numbers of cars, motorcycles, and low-occupancy public transport modes and thus help reduce congestion and energy usage.

This study shows that a package of countermeasures with small improvements in each of the components of the ASIF framework is best able to address the multiple objectives of the city. Such a package will integrate the abilities of each scenario to address a particular objective. Further, by avoiding too much intervention in any one sector, the package is less likely to be unpopular politically. The package would reduce CO_2 emissions by 20%, PM_{10} levels by 47%, the number of cars and motorcycles by 132,824, and energy use by 18%. It would also increase electricity use by 8 million KWh from the baseline case in 2025.

In the Kathmandu Valley, there is more synergy than conflict between local and global objectives. For specific countermeasures, priorites may differ and conflicts may arise, but to meet the overall objectives of the city (as outlined in the policy dialogue), the best choice is a single scenario, whether or not reducing CO_2 emissions is seen as an objective.

This study recommends implementing the countermeasures of the PACKAGE scenario. They include promoting buses and minibuses, restraining private cars and motorcycles, adopting EURO-II emission standards, using 500-ppm diesel and gasoline, expanding trolley buses, and further promoting battery-operated three-wheelers in niche sectors of urban transportation.

Finally, in order to direct future research some limitations of this study must be highlighted. It was greatly hindered by a lack of information about and data on key parameters of the model. The major compromises lie with the emission factors, which are borrowed from various other sources and with the assumptions that were made to disaggregate vehicles by type, fuel, size, and age. Due to the lack of data, the effect of various inspection and maintenance programmes for in-use vehicles on emissions could not be studied. One additional limitation of this research is the weak connection between urbanisation and travel demand. There is almost no past research on this area, so it is difficult to make a judgment. This area needs large-scale research. The author recommends carrying out research to determine the local emission factors of various vehicles by their type, size, speed and age. Developing average emission factors for the fleets is an important first step. While this study provides an emission-based analysis, the actual purpose of emission control is to reduce adverse health impacts. Emission-based studies need to be linked to pollution concentration-related research and to population exposure analyses and health effects. Research on these links in the Valley is lacking. Research would give decision-makers better feedback on their proposed policies and help them evaluate existing policies more effectively and make appropriate and beneficial revisions.

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Annexes

annex ONE

Nepal Vehicle Mass Emission Standard, 2056 (For Gasoline- and Diesel-Operated Vehicles)

A. Vehicles Fuelled with Gasoline (Positive Ignition Engines)

1. For Passenger Cars with up to Six Seats and Gross Vehicle Weights Less Than 2.5 Tonnes

1.1 **Type 1 Test:** Verifying exhaust emissions after a cold start

	CO (g per km)	HC and NO_x (g per km)
Type approval*	2.72	0.97
Conformity of production**	3.16	1.13

Note: The test shall be conducted as per the driving cycle adopted by different countries, with a cold start on a chassis dynamometer. (* Please see the explanatory note. ** Please see the explanatory note.)

1.2 **Type II Test:** Carbon monoxide emission at idling speed

This test applies only to vehicles fuelled with leaded gasoline. The CO content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I test.

1.3 **Type III Test:** Verifying emissions of crankcase gases

The crankcase ventilation system must not permit the emission of any gases into the atmosphere.

1.4 **Type IV Test:** Determination of evaporative emission

This test applies to all vehicles fuelled with leaded and unleaded gasoline. Evaporative emissions shall be less than 2 g/test.

1.5 **Type V Test:** Durability of pollution control devices.

This test applies only to vehicles fuelled with unleaded gasoline. The test represents an endurance test of 80,000 km driven on the road or on a chassis dynamometer.

2. For Light-Duty Commercial Vehicles and Vehicles with Gross Vehicle Weights More Than 2.5 Tonnes

2.1 **Type 1 Test:** Verifying exhaust emissions after a cold start

Reference mass (kg)		CO (g per km)	HC and NO_x (g per km)
RM < 1250	Type approval	2.72	0.97
	Conformity of production	3.16	1.13
1250<RM<1700	Type approval	5.17	1.40
	Conformity of production	6.00	1.60
RM>1700	Type approval	6.90	1.70
	Conformity of production	8.00	2.00

Note:

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

2.2 **Type II Test:** CO emission at idling speed

This test applies to vehicles fuelled with leaded gasoline only. The CO content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I test.

2.3 **Type III Test:** Verifying emissions of crankcase gases

The crankcase ventilation system must not permit the emission of any of the crankcase gases into the atmosphere.

2.4 **Type IV Test:** Determination of evaporative emission

This test applies to all vehicles fuelled with leaded and unleaded gasoline. Evaporative emissions shall be less than 2 g/test.

2.5 **Type V Test:** Durability of pollution control devices

This test applies to vehicles fuelled with both leaded and unleaded gasoline. The test represents an endurance test of 80,000 km driven on the road or on a chassis dynamometer.

3. For Two-and Three-Wheelers

3.1 **Type I Test:** Verifying exhaust emissions after a cold start.

	CO (g per km)		HC and NO_x	
	Two-wheeler	Three-wheeler	Two-wheeler	Three-wheeler
Type approval	2.0	4.0	2.0	2.0
Conformity of production	2.4	4.8	2.4	2.4

Note: The test shall be as per the driving cycle adopted by different countries, with cold start on a chassis dynamometer.

3.2 **Type II Test:** CO emission at idling speed.

This test applies to vehicles fuelled with leaded gasoline only. The CO content by volume of the exhaust gases emitted with engines idling must not exceed 3.5% at the settings used for the Type I test.

3.3 **Type III Test:** Verifying emissions of crankcase gases

The crankcase ventilation system must not permit the emission of any gases into the atmosphere.

3.4 **Type IV Test:** Determination of evaporative emission.

This test applies to vehicles fuelled with leaded and unleaded gasoline. Evaporative emissions shall be less than 2 g/test.

3.5 **Type V Test:** Durability of pollution control devices.

This test applies only to vehicles fuelled with unleaded gasoline. The test represents an endurance test of 80,000 km driven on the road or on a chassis dynamometer.

B. Vehicles Fuelled with Diesel (Compression Ignition Engines)

1. For Passenger Cars with up to Six Seats and Gross Vehicle Weights Less Than 2.5 Tonnes

1.1 **Type 1 Test:** Verifying exhaust emissions after a cold start.

	CO (g per km)	HC and NO_x (g per km)	PM (g per km)
Type approval	2.72	0.97	0.14
Conformity of production	3.16	1.13	0.18

Note: The test shall be as per the driving cycle adopted by different countries, with a cold start on a chassis dynamometer.

1.2 **Type II Test:** CO emission at idling speed

Not applicable

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

1.4 **Type IV Test:** Determination of evaporative emission.
Not applicable

1.5 **Type V Test:** Durability of pollution control devices.
The test represents an endurance test of 80,000 km driven on the road or on a chassis dynamometer.

2. For Light-Duty Commercial Vehicles and Vehicles with Gross Vehicle Weights of More than 2.5 t

2.1 **Type 1 Test:** Verifying exhaust emissions after a cold start

Reference mass		CO (g per km)	HC and NO_x (g per km)	PM (g per km)
RM < 1250 kg	Type approval	2.72	5.17	0.14
	Conformity of production	3.16	1.13	0.18
1250<RM<1700 kg	Type approval	6.9	1.4	0.19
	Conformity of production	8.0	1.6	0.22
RM>1700 kg	Type approval	6.0	1.7	0.25
	Conformity of production	0.97	2.0	0.29

Note: The test shall be as per the driving cycle adopted by different countries, with a cold start on a chassis dynamometer.

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

2.2 **Type II Test:** Carbon monoxide emission at idling speed
Not applicable

2.3 **Type III Test:** Verifying emissions of crankcase gases
The crankcase ventilation system must not permit the emission of any gases into the atmosphere.

2.4 **Type IV Test:** Determination of evaporative emission
Not applicable

2.5 **Type V Test:** Durability of pollution control devices
The test represents an endurance test of 80,000 km driven on the road or on a chassis dynamometer.

3. For Heavy-Duty Vehicles and Vehicles with Gross Vehicle Weights (GVW) of More Than 3.5 Tonnes

3.1 **Type I Test:** Verifying exhaust emissions after a cold start

Pollutant	Type approval	Conformity of production
CO (g per Kw-hr)	4.50	4.90
HC (g per Kw-hr)	1.10	1.23
NO_x (g per Kw-hr)	8.00	9.00
PM (g per Kw-hr) [for engines with power less than 85 Kw]	0.61	0.68
PM (g per Kw-hr) [for engines with power more than 85 Kw]	0.36	0.40

Note: The test shall be as per the test driving cycle adopted by different countries with a 13-mode emissions engines dynamometer test.

3.2 **Type II Test:** CO emission at idling speed
Not applicable

3.3 **Type III Test:** Verifying emissions of crankcase gases
The crankcase ventilation system must not permit the emission of any gases into the atmosphere.

3.4 **Type IV Test:** Determination of evaporative emission
Not applicable

3.5 **Type V Test:** Durability of pollution control devices
The test represents an endurance test of 80,000 km driven on the road or on a chassis dynamometer.

Explanatory Notes

Type approval

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

to the manufacturer's specifications.
The advantage of a certification or type-approval programmes is that it can influence vehicle design prior to mass production. It is more cost effective than other programmes because manufacturers identify and correct problems before production actually begins.

Approval of a vehicle

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

Conformity of production

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

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

annex TWO
National Ambient Air Quality Standards

Parameters	Units	Averaging time	Maximum concentration in ambient air,	Test methods
Annual TSP (total suspended particulates)	µg/m3	Annual 24 hours *	- 230	High-volume sampling
PM_{10}	µg/m3	Annual 24 hours *	- 120	Low-volume sampling
SO_2	µg/m3	Annual 24 hours **	50 70	Diffusive sampling based on weekly averages To be determined before 2005
NO_2	µg/m3	Annual 24 hours **	40 80	Diffusive sampling based on weekly averages To be determined before 2005
CO	µg/m3	8 hours** 15 minutes	10,000 100,000	To be determined before 2005 Indicative samples ***
Lead	µg/m3	Annual 24 hours	0.5 –	Atomic absorption spectrometry, analysis of PM_{10} samples****
Benzene	µg/m3	Annual 24 hours	20**** –	Diffusive sampling based on weekly averages

Note: *The 24-hour values shall be met 95% of the time in a year. The standard may be exceeded on 18 days per calendar year but not on two consecutive days.

**The 24-hour standards for NO_2 and SO_2 and the eight-hour standard for CO are not to be controlled before the MOPE has recommended appropriate testing methodologies. This will be done before 2005.

*** Control by spot sampling at roadside locations. A minimum of one sample per week was taken over 15 minutes during peak traffic hours, i.e. from 8 a.m. to 10 a.m. or from 3 p.m. to 6 p.m. on a workday. This test method will be re-evaluated by 2005.

**** Representativeness can be proven and yearly averages can be calculated from PM_{10} samples from selected weekdays from each month of the year.

***** To be re-evaluated by 2005.

annex THREE

Table A1 Total number of vehicles registered in the Bagmati Zone

Vehicle Type	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Bus			560	663	718	792	958	1,045	1,163	1,298	1,403	1,632	1,744	1,858	2,061	2,214
Minibus			1,024	1,168	1,277	1,352	1,388	1,430	1,468	1,500	1,527	1,610	1,804	2,172	2,387	2,437
Bus Minibus	1,468	1,526	1,584	1,831	1,995	2,144	2,346	2,475	2,631	2,798	2,930	3,242	3,548	4,030	4,448	4,651
Truck/Tanker			2,292	2,631	2,950	3,343	3,781	4,113	4,483	4,759	4,811	5,295	5,484	6,274	6,991	7,370
Car/Jeep/Van	14,617	15,621	16,625	17,867	19,244	20,748	22,640	24,801	27,153	28,915	30,919	35,993	40,674	43,409	45,361	51,541
Pick-up															521	999
Microbus															232	902
Three wheeler	1,638	1,746	1,854	2,666	3,844	3,844	3,844	3,844	3,844	3,925	4,262	4,778	4,949	5,073	5,073	5,085
Two wheeler	18,520	20,440	22,359	28,407	32,240	37,774	43,506	49,299	58,029	64,142	71,612	94,217	112,000	134,852	156,410	73,6461
Tractor	557		1,156	1,349	1,615	1,623	1,635	1,670	1,672	1,672	1,672	1,672	1,673	1,673	1,677	1,677
Other						2,561	2,678	3,012	3,020	3,278	3,311	3,338	3,350	3,356	3,385	3,411
Total	**36,800**	**39,333**	**45,870**	**54,751**	**61,888**	**72,037**	**80,430**	**89,214**	**100,832**	**109,489**	**119,517**	**148,535**	**171,678**	**198,667**	**224,098**	**49,282**

Note: Source: DOTM. 1989/90 data was not available so it was interpolated. From 1988/89 to 1992/93 the data includes both for bus and minibus data.

All data are for July 1 of the year specified; 2004 means 2003/2004

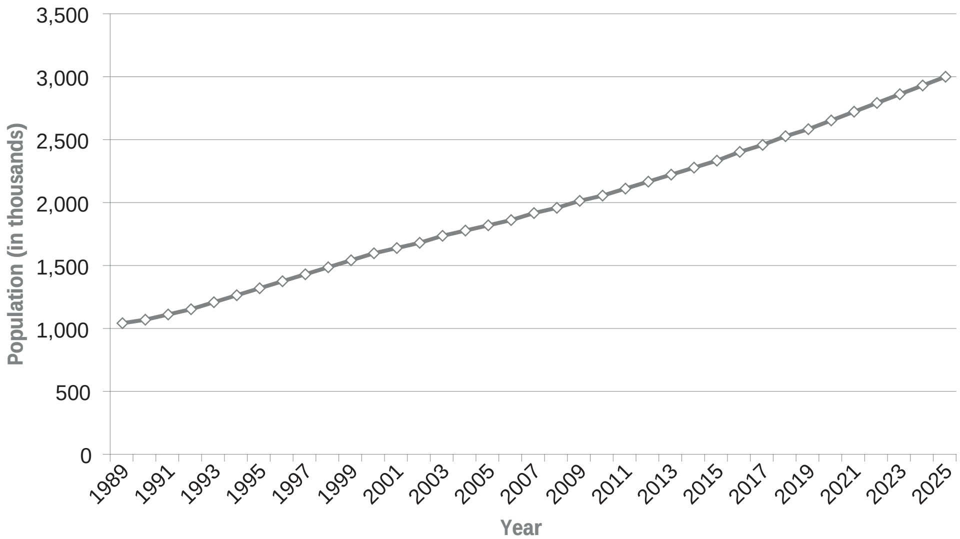

Figure A1 **Valley population: past and future**

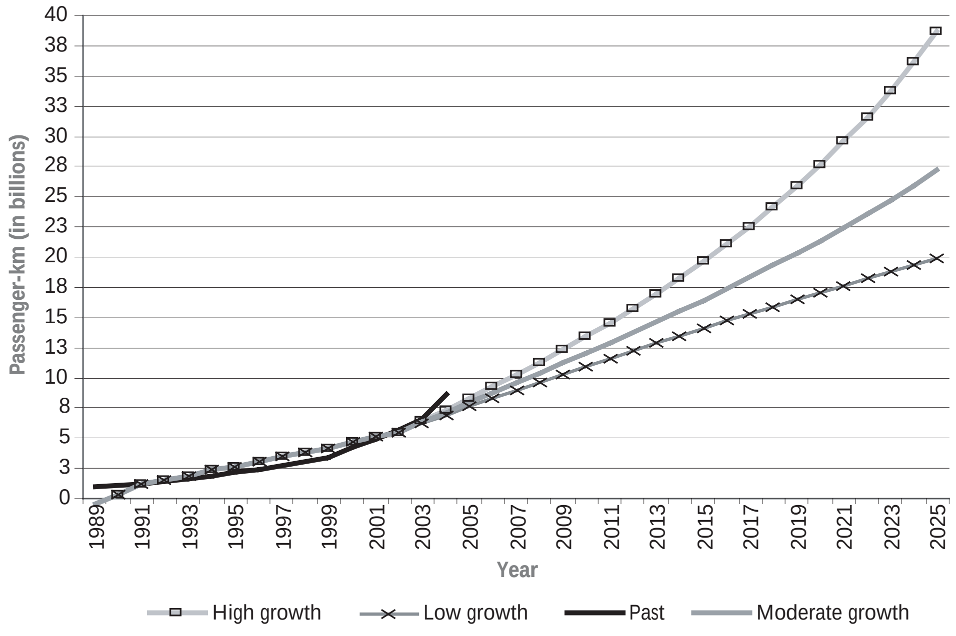

Figure A2 **Travel demand under assumptions of low, moderate, and high economic growth**

Table A2 Estimated number of vehicles in baseline scenario

Year	Private cars per 100 people	Motorcycle per 100 people	No. of cars	No. of motorcycles	Total no. of vehicles	Total no. of vehicles per km of road[56]
2004	1.79	6.85	31,837	121,550	171,207	129
2005	1.84	6.93	33,387	126,067	177,269	134
2006	1.90	7.10	35,445	132,352	186,386	141
2007	1.98	7.33	37,958	140,141	197,661	149
2008	2.08	7.61	40,874	149,193	210,764	159
2009	2.20	7.92	44,150	159,296	225,407	170
2010	2.32	8.26	47,744	170,261	241,333	182
2011	2.44	8.60	51,622	181,924	258,318	195
2012	2.57	8.95	55,755	194,150	276,175	209
2013	2.70	9.30	60,120	206,826	294,755	223
2014	2.84	9.64	64,700	219,867	313,943	238
2015	2.97	9.97	69,485	233,215	333,662	252
2016	3.11	10.29	74,474	246,837	353,873	268
2017	3.24	10.60	79,673	260,725	374,569	283
2018	3.38	10.90	85,095	274,899	395,792	300
2019	3.51	11.19	90,765	289,405	417,613	316
2020	3.65	11.48	96,714	304,317	440,147	333
2021	3.79	11.76	102,987	319,734	463,550	351
2022	3.93	12.05	109,638	335,783	488,018	369
2023	4.08	12.34	116,733	352,616	513,787	389
2024	4.24	12.64	124,353	370,415	541,139	410
2025	4.41	12.95	132,590	389,388	570,399	432

56 Assuming that there will be no significant increase in the road length in the Valley.

Table A3 Average fuel efficiencies of new cars

Year	Light duty gasoline vehicle	Light duty diesel vehicle	Diesel microbus	LPG microbus	Diesel bus	Trolley bus	Diesel minibus	Three-wheeler battery	Three-wheeler LPG	Two-stroke Two-wheeler	Four-stroke Two-wheeler
2004	16	12	10	8	4	0.75	8	5.83	14.7	40	55
2005	16.15	12.11	10.09	8.07	4.03	0.75	8.07	5.83	14.7	40	55
2006	16.3	12.22	10.18	8.14	4.06	0.75	8.14	5.83	14.7	40	55
2007	16.45	12.33	10.27	8.21	4.09	0.75	8.21	5.83	14.7	40	55
2008	16.6	12.44	10.36	8.28	4.12	0.75	8.28	5.83	14.7	40	55
2009	16.75	12.55	10.45	8.35	4.15	0.75	8.35	5.83	14.7	40	55
2010	16.9	12.66	10.54	8.42	4.18	0.75	8.42	5.83	14.7	40	55
2011	17.05	12.77	10.63	8.49	4.21	0.75	8.49	5.83	14.7	40	55
2012	17.2	12.88	10.72	8.56	4.24	0.75	8.56	5.83	14.7	40	55
2013	17.35	12.99	10.81	8.63	4.27	0.75	8.63	5.83	14.7	40	55
2014	17.5	13.1	10.9	8.7	4.3	0.75	8.7	5.83	14.7	40	55
2015	17.65	13.21	10.99	8.77	4.33	0.75	8.77	5.83	14.7	40	55
2016	17.8	13.32	11.08	8.84	4.36	0.75	8.84	5.83	14.7	40	55
2017	17.95	13.43	11.17	8.91	4.39	0.75	8.91	5.83	14.7	40	55
2018	18.1	13.54	11.26	8.98	4.42	0.75	8.98	5.83	14.7	40	55
2019	18.25	13.65	11.35	9.05	4.45	0.75	9.05	5.83	14.7	40	55
2020	18.4	13.76	11.44	9.12	4.48	0.75	9.12	5.83	14.7	40	55
2021	18.55	13.87	11.53	9.19	4.51	0.75	9.19	5.83	14.7	40	55
2022	18.7	13.98	11.62	9.26	4.54	0.75	9.26	5.83	14.7	40	55
2023	18.85	14.09	11.71	9.33	4.57	0.75	9.33	5.83	14.7	40	55
2024	19	14.2	11.8	9.4	4.6	0.75	9.4	5.83	14.7	40	55
2025	19.2	14.4	12	9.6	4.8	0.75	9.6	5.83	14.7	40	55

Table A4 Average fuel efficiencies of vehicle fleets

Year	Light duty gasoline vehicle	Light duty diesel vehicle	Diesel microbus	LPG microbus	Diesel bus	Trolley bus	Diesel minibus	Three-wheeler battery	Three-wheeler LPG	Two-stroke Two-wheeler	Four-stroke Two-wheeler
2004	11.34	8.00	8.00	8.00	3.90	0.75	5.40	5.83	14.70	38.40	53.80
2005	11.82	8.41	8.43	8.01	3.92	0.75	5.74	5.83	14.70	38.33	53.93
2006	12.31	8.83	8.51	8.02	3.93	0.75	6.06	5.83	14.70	38.26	54.05
2007	12.78	9.23	8.61	8.03	3.95	0.75	6.35	5.83	14.70	38.10	54.16
2008	13.23	9.60	8.72	8.05	3.98	0.75	6.61	5.83	14.70	37.91	54.28
2009	13.63	9.94	8.83	8.06	4.00	0.75	6.85	5.83	14.70	36.80	54.37
2010	14.00	10.25	8.94	8.09	4.02	0.75	7.05	5.83	14.70	36.80	54.45
2011	14.28	10.47	9.04	8.11	4.05	0.75	7.17	5.83	14.70	36.80	54.55
2012	14.53	10.68	9.15	8.14	4.08	0.75	7.29	5.83	14.70	36.80	54.62
2013	14.78	10.89	9.25	8.17	4.11	0.75	7.44	5.83	14.70	36.80	54.68
2014	15.02	11.08	9.35	8.20	4.13	0.75	7.56	5.83	14.70	36.80	54.73
2015	15.24	11.26	9.44	8.24	4.15	0.75	7.65	5.83	14.70	36.80	54.77
2016	15.46	11.44	9.53	8.27	4.19	0.75	7.73	5.83	14.70	36.80	54.80
2017	15.67	11.61	9.62	8.30	4.21	0.75	7.81	5.83	14.70	36.80	54.82
2018	15.88	11.77	9.70	8.34	4.24	0.75	7.88	5.83	14.70	36.80	54.84
2019	16.06	11.91	9.79	8.37	4.26	0.75	7.95	5.83	14.70	36.80	54.85
2020	16.24	12.06	9.87	8.57	4.29	0.75	8.01	5.83	14.70	36.80	54.86
2021	16.46	12.23	9.95	8.62	4.33	0.75	8.09	5.83	14.70	36.80	54.86
2022	16.67	12.40	10.03	8.67	4.35	0.75	8.20	5.83	14.70	36.80	54.87
2023	16.84	12.53	10.51	8.71	4.37	0.75	8.34	5.83	14.70	36.80	54.88
2024	17.01	12.66	10.59	8.76	4.41	0.75	8.44	5.83	14.70	36.80	54.88
2025	17.24	12.84	10.71	8.83	4.45	0.75	8.50	5.83	14.70	36.80	54.89

This study presents analyses of the current status of the emission of air pollutants and carbon dioxide (CO_2) and the energy use in the Kathmandu Valley which is associated with urban passenger transportation. It also includes a discussion of past trends and future scenarios in order to help identify plausible synergistic mitigation measures. In this pursuit, the study developed an inventory of priority air pollutants, energy use and CO_2 emission associated with passenger transportation in the Kathmandu Valley for the past and projected these values into the future with the help of a bottom-up, dynamic accounting model and a scenario approach. In the process, a policy dialogue was held with relevant stakeholders in the Valley to identify issues of local priority (which were identified as PM10 emissions, congestion and energy use), past achievements, and the potential present and future avenues for policy interventions in the Valley. Using the outcomes of this dialogue, available data, and an accounting model, a number of scenarios that reflect local conditions and potential intervention avenues were formulated. These scenarios were then evaluated using a few indicators that are relevant to the local context (changes in PM_{10} emissions, number of vehicles, and conservation of energy and utilisation of indigenous energy resources) and the global context (mitigation of CO_2 emissions).

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