

Climate Change Mitigation in the Urban Transport Sector

Priorities for the World Bank



CLIMATE CHANGE MITIGATION IN THE URBAN TRANSPORT SECTOR

PRIORITIES FOR THE WORLD BANK

Stephen Karekezi and Lugard Majoro
African Energy Policy Research Network

Todd M. Johnson
Environment Department, The World Bank

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ABBREVIATIONS, ACRONYMS, AND GLOSSARY

ALS	Area Licensing Scheme (Singapore)
BRT	Bus rapid transit
CNG	Compressed natural gas
CO	Carbon monoxide
CO ₂	Carbon dioxide (a greenhouse gas)
Euro II	Vehicle emission standard for Europe
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse gas (gas which contributes to climate change effects)
GPS	Global positioning system
HC	Hydrocarbon
HOV	High occupancy vehicle
ICE	Internal combustion engine
IEA	International Energy Agency (OECD, Paris)
IPCC	Intergovernmental Panel on Climate Change
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
LRT	Light rail transit
MRT	Mass rapid transit
NMT	Non-motorized transport
NO	Nitric oxide
NO ₂	Nitrogen dioxide
NO _x	Oxides of nitrogen

OECD	Organization for Economic Cooperation and Development (association of mainly industrial countries)
OP11	GEF Operational Program #11 on Sustainable Transport
PIF	Policy, institutional, and fiscal issues
PM ₁₀	Particulate matter of size 10 microns or smaller in aerodynamic diameter, also referred to as inhalable particulate matter
PM _{2.5}	Particulate matter of size 2.5 microns or smaller in aerodynamic diameter, also referred to as respirable particulate matter or fine particulate matter
SO ₂	Sulfur dioxide
SO _x	Oxides of sulfur
STAP	GEF's Scientific and Technical Advisory Panel
TDM	Traffic demand management
TSP	Total suspended particles
UNDP	United Nations Development Program
UTS	Urban Transport Strategy of the World Bank
VOC	Volatile organic compound

Units

mg	Micrograms (10 ⁻⁶ grams)
mg/m ³	Micrograms per cubic meter
g/km	Grams per kilometer
g/l	Grams per liter
GJ	Gigajoules, 10 ⁹ Joules, a unit of energy
kg	Kilograms
kg/l	Kilograms per liter, a unit of density
kg/m ³	Kilograms per cubic meter, a unit of density
km	Kilometer
kph	Kilometers per hour
pphpd	Passengers per hour per direction



EXECUTIVE SUMMARY

The transport sector accounts for a large share of global greenhouse gas emissions, and this share is expected to grow over the coming decades. In developing countries, although transport's share of GHG emissions is low, energy consumption within the transport sector is usually growing much faster than in other sectors. Despite the transport sector's importance to global GHG emissions, the focus of GHG mitigation efforts by the Global Environment Facility (GEF), other multilateral and bilateral actors, and the international carbon market, have generally been outside the transport sector. This is partly due to the perception that there are less costly mitigation options in other sectors, but also has to do with a lack of exploration and analysis of GHG reduction options related to transportation.

The Global Environment Facility's Operational Program on Sustainable Transport (OP11) presents opportunities and challenges for developing countries and the World Bank

to address the climate change impacts of the transport sector. The purpose of this paper is to help identify interventions within the urban transport sector that are both consistent with the national priorities of developing countries and with the GEF's climate change objectives.

The analysis begins with a review of the World Bank's urban transport strategy (2002), reflecting a concerted effort to identify priorities for the sector within developing countries. These priorities are then compared with the emerging global environmental objectives of the GEF's OP11. This analysis reveals the following areas of overlap:

- Promotion of low-cost public transport modes, such as bus rapid transit
- Non-motorized transport, including bikeways and pedestrian walkways
- Transport and urban planning to facilitate efficient and low-GHG modes of transportation

- Transport demand management measures that favor or enable public transport and NMT.

Given the paucity of information on the GHG emissions associated with urban transport, which has hindered GEF and other funding support for the above measures, it is important to evaluate and document the climate change benefits of various interventions and policies within the urban transport sector.

By providing a framework and examples of how the World Bank can address climate change through its involvement in the urban transport sector, it is hoped that new interventions will be proposed for GEF support. While this paper is limited to the urban transport sector, there is a need to identify similar opportunities and overlap between OP11 and World Bank priorities for other transport issues, such as long-distance freight and passenger transport.



1.0 OBJECTIVE AND STRUCTURE

A major challenge for the World Bank and other development institutions is to identify appropriate interventions in the transport sector for climate change mitigation. In many developing countries, energy consumption and greenhouse gas (GHG) emissions are growing faster in the transport sector than in other sectors. However, many of the advanced vehicle technologies that have been proposed to reduce GHG emissions are not part of the near-term developmental agenda in cities in developing countries because of their high cost and the lack of infrastructure (for example, fueling) and institutional systems. From an international carbon financing perspective, many of the technology-focused interventions in the transport sector are also too expensive compared with GHG reduction options in other sectors.

The Global Environment Facility (GEF), which provides funding to developing countries for climate change mitigation, is interested in identifying interventions in the trans-

port sector that are not only cost-effective but also consistent with other developmental priorities. In 1999, the GEF established an operational program for sustainable transport (OP11) to provide grant support to developing countries for interventions in the transport sector aimed at reducing GHG emissions. In the first three years of the OP11 program, the majority of funding went to projects for advanced transport technologies. Wishing to balance the OP11 portfolio and recognizing the limitations of GEF funding to significantly lower the cost of precommercial transport technologies, the Scientific and Technical Advisory Panel (STAP) of the GEF convened a workshop in March 2002 to discuss nontechnological options for OP11. This paper incorporates many of the recommendations that came from that workshop.

The World Bank supports a large number of urban transportation projects and programs throughout the developing world and in the transition economies. In 2002, the Bank com-

pleted a new strategy paper for the urban transport sector. Given the growth of GHG emissions from the transport sector in developing countries and the Bank's commitment to help developing countries mitigate GHG emissions, it is important that the Bank identify feasible ways to reduce the carbon intensity of urban transport projects while still meeting other objectives of urban transport projects. This paper proposes options for mitigating climate change concerns that are consistent with the Bank's urban transport strategy (UTS) and the climate change objectives of the GEF.

The paper is organized as follows. Section two examines the Bank's UTS and identifies

four key elements of the strategy that are relevant to climate change mitigation. Section three discusses the environmental dimensions of the UTS from a local urban environment perspective and a global climate change perspective. Case examples of ongoing and planned urban transport initiatives are provided to illustrate their GHG mitigation potential. The final part of section three compares priorities emerging from the UTS with those of the GEF's program for sustainable transport (OP11). Section four summarizes an approach whereby the World Bank can best integrate climate change concerns within its urban transport program in developing countries.



2.0

THE WORLD BANK'S URBAN TRANSPORT STRATEGY

The World Bank's urban transport strategy places transport needs within a broad context of urban development. Previous Bank strategies had focused largely on improving the management and financial viability of urban transport systems. The latest strategy addresses in more detail the relationship of urban transport to poverty alleviation, the critical role of non-motorized transport, and the effects of the external environment on the transport sector.

The UTS reviews the negative effects that rapid urbanization and motorization have had on urban areas in the developing world. Many developing countries are registering urban population growth rates in excess of 6 percent annually and the number of cities with populations exceeding 10 million is expected to double within the next 25 years. Of concern from a climate change perspective is that GHG emissions are increasing most rapidly from private motor vehicle use. Some countries are registering an annual

Box 1 Bicycles on the Retreat in China

China is the world's largest bicycle producer and has the largest bicycle fleet of any nation. However, since the early 1990s, bicycle use has been under pressure from road vehicles. In the city of Guangzhou, bicycle usage plummeted from 33 percent of all trips in 1995 to less than 20 percent in 2002. In Shanghai, trips by bike dropped from 33 percent in 1995 to 27 percent in 2000. Many urban cyclists have voluntarily given up their bicycles as more convenient and faster modes of transportation have become available. However, bicyclists are also being forced off the road through physical limitations and safety considerations. In major cities such as Beijing, bicyclists are being squeezed by motor vehicles that park or drive in bicycle lanes. Bicycle parking at workplaces is reportedly being moved to distant, inconvenient locations to provide more space for motor vehicle parking. Safety concerns for both pedestrians and cyclists have also led to changes in travel patterns. Traffic deaths in China doubled between 1990 and 2000, with cyclists accounting for 38 percent of the fatalities, or around 38,000 deaths.

Sources: ITDP 1999, World Bank 2002b.

growth in per-capita vehicle ownership of 15 to 20 percent. In countries such as China, more climate-friendly modes of transport such as walking and cycling, as well as public transit systems (buses, light rail transit, metros), are being crowded out by the rapidly growing private vehicle fleet (Box 1). Related problems of traffic congestion, road safety, and local air pollution also stem in part from the increasing number of private vehicles. Urban development trends in cities in many developing countries are compounding these problems by encouraging sprawling settlement patterns that often increase the reliance on private motor vehicles and make it even more difficult to provide convenient and affordable transport options for the poor.

The UTS also identifies new developments in the urban transport sector of the developing world. The first such development is the growing and central role that cities play in global trade, which underlines the need for efficient transport systems. The second is the deterioration in the urban transport system, which is partly linked to drastic cutbacks in funding for public transport systems. More recently, the safety and security of urban travelers has become a major concern in many developing countries.

To address the aforementioned challenges, the UTS proposes the following four main responses:

- (i) Structural changes to land use
- (ii) Improved operational efficiency of the transport modes
- (iii) Better focusing of interventions to assist the poor
- (iv) Policy, institutional, and fiscal reforms (PIF).

2.1 Structural Changes to Land Use

On structural changes to land use, the UTS questions the feasibility of trying to solve traffic congestion by shifting activity away from megacities. It argues that there is no reliable indicator of the most effective size of a city beyond which the economies of agglomeration cease. However, the UTS emphasizes that the removal of fiscal and public expenditure distortions that encourage the growth of megacities may still be warranted. It also underlines the need for coordinated and integrated planning of land use and for development of urban transport infrastructure, and stresses that a good road infrastructure does not necessarily result in auto dependency. As seen in Singapore, the demand for and efficiency of the transport sector is directly related to land-use planning (Box 2). Infrastructure can be designed to prioritize the movement of public and non-motorized transport, as done in Bogota and Curitiba (Appendices 1 and 2).

2.2 Improved Operational Efficiency

The Road System

The UTS recommends further efforts to improve transport efficiency through better sys-

Box 2
Integrated Land-Use and Transport Planning — The Case of Singapore

Having witnessed the traffic problems experienced by major cities in both industrial and developing countries, Singapore took a coordinated approach to land-use planning and investment in transportation infrastructure in the early stages of city development following independence in 1965.

A State and City Planning (SCP) Project was commissioned in 1967 with the assistance of the UNDP, to undertake a planning exercise to the year 1992. In line with the SCP Project’s master development plan, the Government of Singapore launched a housing program in the early 1970s to build affordable high-rise housing, complete with supporting commercial, recreational, and public premises in designated zones. This scheme succeeded in moving the city-center dwellers to residential zones. Today, 86 percent of Singapore’s population lives in high-rise residential buildings constructed by the government throughout the island.

Land-use patterns in Singapore facilitated transportation planning. Based on a “ring concept,” high-density residential areas, industries, and urban centers encircle the central business district. The ring concept has two key advantages: (i) the ring form fits in well with the existing city business district along the central portion of the southern coastline; and (ii) the ring plan distributes the areas of activity centers fairly evenly over the island.

Sources: Fwa 2002, World Bank 2002b.

tem management. It points out that technical assistance and investment in this field can yield high returns, as long as fundamental institutional and human resource problems are addressed. Linked to this issue is the urgent need to reverse the urban road decay now occurring in many developing countries. Key reasons for this decay include the absence of clarity concerning which institutions have jurisdiction over urban road development and maintenance, as well as inadequate funding.

Non-Motorized Transport

According to the World Bank UTS, non-motorized transport (NMT) is systematically neglected in urban transport policy, infrastructure development, and traffic manage-

ment. Most cities lack continuous and secure NMT infrastructure. The needs and priorities of pedestrians and cyclists rarely feature in urban transport policy, and road fund statutes and procedures do not make significant allocations for investments in NMT. The UTS stresses that a functional NMT infrastructure serves people in all income groups and is not necessarily confined to the poor. The benefits of a good NMT system to the poor are, however, likely to be higher than to people in other income classes, because NMT is often the only mode of transport that the poor can afford. Traffic management is largely designed to improve the flow of motorized vehicles rather than the movement and safety of people. For example, in New Delhi and Bangkok, 14 percent and 16 per-

cent, respectively, of fatal accidents in 1998 were suffered by cyclists (IPCC 2000). In addition, the UTS emphasizes the need to channel small credit support for financing of bicycle procurement and requisite small-scale enterprises (for example, wholesale and retail outlets, spare parts and repair establishments) to ensure a robust bicycle sector.

Public Passenger Transport

The UTS recommends the promotion of exclusive busways, which are relatively low-cost and can deliver performance levels only slightly lower than much costlier rail-based mass transit systems (Table 1). The UTS is less enthusiastic about the viability of non-exclusive bus lanes combined with auto-

Table 1. Mass Transit Options

Characteristics	Busways	Light rail transit	Metro	Suburban rail
Segregation	At grade	At grade	Mostly elevated or underground	At grade
Required space	2 to 4 lanes ¹ from an existing road	2 to 3 lanes from an existing road	Elevated or underground; little impact on existing road	-
Impact on traffic	Depends on policy or design	Depends on policy or design	Reduces congestion somewhat	Railway crossings may increase congestion when frequencies are high
Public transport integration	Straightforward with bus operations; problematic with paratransit	Often difficult	Often difficult	Often difficult
Initial cost (US\$million/kilometer[km])	1–5	10–30	15–30 at grade 30–75 elevated 60–180 underground	-
Capacity (passengers/hour/direction)	10–20,000 ²	10–12,000	More than 60,000	30,000 ³
Operating speed (kilometers per hour [kph])	17–20	20	30–40	40–50
Examples	Quito, Singapore	Tunis; most European and North American cities	Most European and North American cities	Most European and North American cities

Notes:

1. Two and four lane bus systems have been put in the same category for ease of comparing BRT and the other modes. It is important to note the advantages of the four lane BRT systems that allow passing and express services, hence higher speeds and capacities of up to 45,000 pphpd according to the theoretical Transmilenio capacity. However, few streets can accommodate a four lane BRT system. Two lane BRT systems are generally limited to below 20,000 pphpd.

2. Could be as high as 35,000 passengers per hour per direction in a two-lane system, based on the example of Bogota, Colombia. Gardner et al. (1991) found that a basic two-lane, two-way busway serving a busy corridor and without special operational measures can accommodate 11,000–15,000 passengers/hour/direction. Of the eight busways studied, the highest capacity recorded was 26,000 passengers/hour/direction in Porto Alegre, Brazil. Movement was in the predominantly alighting direction.

3. Suburban railways have less capacity than the metro because (i) at-grade crossings reduce their speed; (ii) they usually share rails with freight trains; and (iii) most were not built for efficient transportation of passengers.

Sources: Fox 2000, Hook and Wright 2002.

mated priority at intersections. Enforcement of non-exclusive bus lanes has, in practice, proven to be very difficult. The UTS is also cautious about recommending that developing countries invest in urban rail systems because of the high capital and operational costs. Experience has also demonstrated that poorly planned urban rail systems can harm the interests of poor bus users and impose a large financial burden on cities.

2.3 Better Focusing of Interventions to Assist the Poor

Targeting the Poor

The use of transport infrastructure is unevenly distributed in many countries in the world. A study in Cairo, Egypt, for example, found that 10 percent of the population use 54 percent of the space dedicated to transport (Metge 2000). In Bogota, prior to the introduction of the bus rapid transit system, about 71 percent of motorized trips were made by bus, while 95 percent of the road space was used by private cars that transported only 19 percent of the population (GEF 2002a). In both of these cases, middle- and high-income people use a disproportionate share of the transport infrastructure. Two options the UTS recommends to remedy this imbalance are concentrating efforts in improving access to slum areas and improving public transport to peripheral locations. However, the UTS warns that investments in primary roads and high-cost transit systems can change the value of land and eventually drive the poor out of the area. Investments in primary roads

and high-cost mass transit systems can have the perverse effect of driving out poor people as a result of escalating land and property values. Preference should be given to improving NMT and bus systems—modes of transport that more directly serve the poor.

Safety and Security

The UTS emphasizes the need not only to focus on the poor but also to consider other disadvantaged groups, such as women, the old, and the infirm, who are particularly vulnerable to traffic safety and security problems. Road accidents are a major global problem. Close to half a million people die and up to 15 million are injured in urban road accidents in developing countries each year. This translates into a direct economic cost of 1 to 2 percent of gross domestic product (GDP). A significant proportion of these victims are poor pedestrians and cyclists, who account for more than 40 percent of the transport-related deaths in developing countries (Maddison et al. 1996; ICE 2000). The UTS recommends that as first steps, developing countries need to strengthen national road accident data collection and analysis capability and ensure the existence of institutional arrangements that allow data to be shared with those in charge of urban transport policy formulation and implementation. The UTS report also notes that road accidents can be reduced by improved NMT infrastructure, enhanced road design, and better traffic-management policies. Public participation at the neighborhood level can play an important role in improving urban transport safety and

security. Street lighting, especially in slum upgrading projects, can be particularly effective in making urban transport systems more secure.

2.4 Policy, Institutional, and Fiscal Reforms

The UTS emphasizes that technical measures alone are unlikely to adequately address the urban transport challenge in developing countries. This is due to three structural characteristics (World Bank 2002b) that are unique to the urban transport subsector:

- (i) The separation of infrastructure from operations
- (ii) The separation of interactive modes of transport
- (iii) The separation of infrastructure financing from infrastructure pricing.

Consequently, the UTS's main recommendations for policy and institutional reform are aimed at integrating the disparate elements of current urban transport policies in many cities of the developing world. The UTS calls for an integrated package of strategies for infrastructure and service pricing and for system financing. At the institutional level, it recommends greater integration of the disparate authorities and agencies that currently oversee the urban transport subsector to facilitate a more cohesive approach to policy formulation and implementation.

Charging for Infrastructure

While the UTS concedes that, in the long term, congestion pricing is the preferred op-

tion, it stresses that the current institutional and technical capacity in many developing countries is not yet sufficient to ensure successful implementation of congestion pricing. The UTS therefore proposes a second-best package of measures to realize some of the benefits of congestion pricing. The proposed measures include fuel taxation, vehicle license duties, and parking charges. For example, the area licensing scheme (ALS) implemented in Singapore was effective in reducing total vehicular traffic (see Box 3).

Box 3

The Area Licensing Scheme in Singapore

Between 1972 and 1992, Singapore instituted various measures to control the ownership and use of private automobiles. It implemented the area licensing scheme to restrict access to the central business district. The ALS reduced total vehicular traffic in the central business district by 50 percent and reduced private traffic by 75 percent. The ALS is being replaced with electronic road pricing, which uses an electronic in-vehicle device to monitor road access and congestion charges. The new system has resulted in additional vehicle reductions of 20 to 24 percent (from 271,000 to 216,000 vehicles per day). Average speeds have increased from 30–35 kph to 40–45 kph.

The overall goal of transportation planning and management in Singapore is to encourage the use of public transport and to restrict car usage. To control vehicle ownership, registration fees have been used. The fees, which increased from 10 percent of the vehicle price in 1972 to 175 percent in 1983, were instrumental in controlling vehicle ownership.

Sources: Fwa 2002; World Bank 2002b.

Service Pricing

Given the high levels of interaction between modes of urban transportation (e.g. private, public, non-motorized), the UTS strongly endorses the need for service pricing principles that promote the integration of urban transport. The UTS emphasizes, however, that an integrated urban transport approach is not a reason for establishing a monopoly supplier of transport services. Competitive service suppliers driven by pure commercial objectives can be organized through contracts with municipal authorities with non-commercial objectives via transparent and direct subsidies. Well-managed competition can be pro-poor. Poorly managed deregulation, as in case of Lima, Peru, can result in increased road congestion and pollution and deteriorating safety and security. The UTS also argues that low fares, cross-subsidies, and service controls do not always work in the interest of the poor. Such policies often lead to the deterioration, and in some cases the collapse, of public transport systems on which the poor rely.

Urban Transport Financing

Given the need to integrate different urban transport modes, the UTS contends that urban transport financing should be fungible. For example, revenues raised from private auto users can be used to finance improvements in public transport. The UTS expresses support for a centralized urban transport fund that would facilitate coordination of fiscal transfers. However, it underscores the need

for securing political and popular support for a centralized fund backed by a transparent and well-managed unitary authority, such as the one in Singapore. The UTS agrees that there is a role for the private sector in the financing of urban transport, but believes that any private activity should be undertaken only within the context of an overall urban transport strategy.

Integrated Institutional Framework

An integrated institutional framework is required to ensure that urban transport is coordinated with urban land-use planning. In addition, some form of integration at the institutional level is required to ensure that:

- (i) The necessary land and rights-of-way for urban transport infrastructure are secured
- (ii) The requisite funding commitments and guarantees are made
- (iii) Physical coordination (to facilitate smooth modal interchange) and fares coordination (to maintain and improve public transport systems and protect the poor) are part of a comprehensive urban transport strategy plan (see Box 4).

Comprehensive Urban Transport Strategy Plan

The UTS calls for the formulation and implementation of comprehensive urban transport plans. Such plans can provide the basis for establishing an integrated institutional framework that clearly allocates responsibilities and functions among various agencies. Statu-

Box 4 Integrated Public Transport System — Quito, Ecuador

Prior to the mid-1990s, more than 10 institutions were responsible for urban transport in Ecuador. The highest transport authority in Ecuador, the National Transport Council (Consejo Nacional de Tránsito), was represented by the government, drivers' unions, the police, and the army. Decisions, when they could be reached, were the result of political compromise among these groups.

In Quito, the public transportation system comprised vehicles run by authorized associations (accounting for 90 percent of all vehicles), the municipality, and unauthorized vehicle owners. Bus owners in Ecuador usually rented their vehicles to drivers for a certain number of days, in return for a percentage of the total earnings from the vehicles. This practice encouraged drivers to carry the maximum number of passengers and to work long hours, among a host of other unsafe tactics.

To streamline the transport system, in 1994, the Ecuadorian Congress granted to the municipality of Quito responsibility for “the planning, regulation and coordination of all matters related to public and private transport.” Through a technical unit, the municipality would supervise and control the performance and level of service in the transport sector of Quito. An integrated public transport system was set up. The first phase had the following components:

- A central corridor line (11.2 km) with exclusive trolley bus lanes
- Two transfer stations, where passengers transfer from the trolley line to a feeder system served by regular buses
- 39 trolley bus stops with a preboarding fare system
- 70 feeder buses with a capacity of 80 passengers each that serve the outskirts of the city
- 54 articulated trolley buses with a capacity of 180 passengers each that run along the exclusive bus line.

The improved transport system resulted in a reduction in travel time of up to 50 percent and has saved about 18,000 person hours per day. Studies have also estimated a significant reduction in air pollution along the central trolley bus line. The air pollution benefits are mainly attributable to the elimination of old buses (had an average age of 18 years) and to the coordinated signal system, which improved traffic movement.

Source: Arias 2002.

tory obligations imposed on municipal authorities for transport services should be linked to specific financial flows. Effective involvement of the private sector requires the explicit separation of technical regulation from procurement and financial regulation. While it may not be feasible to develop a comprehensive urban transport strategy plan for every major city in the developing world,

it is important to ensure that any planning initiative that is undertaken does not jeopardize the possibility of instituting a comprehensive urban transport strategy.

Involvement of the Informal Sector

The UTS notes that most institutional reforms in the urban transport sector of the developing world have failed to enlist the informal

paratransit sector, composed of low-cost and small vehicles, that serve the poor. Too often, this sector is perceived as a problem rather than as part of the solution. While regulatory controls and enforcement are required

to reduce anticompetitive and antisocial behavior, it is important to ensure that small informal operators have an opportunity to provide transport services in a competitive and properly regulated manner.



3.0 ALIGNMENT WITH THE GEF'S CLIMATE CHANGE PRIORITIES FOR TRANSPORT

The extent to which developing countries would undertake climate change mitigation activities in the urban transport sector is dependent on degree of overlap between climate change goals and more immediate environmental, social, and economic concerns. It is thus instructive to look at how the World Bank's urban transport strategy addresses environment issues, particularly climate change, in the light of the GEF's priorities for transport. Established in 1999, the GEF's sustainable transport program provides support to developing countries for climate change mitigation. In March 2002, the Scientific and Technical Advisory Panel (STAP) of the GEF organized a workshop on sustainable transport to discuss how to better align OP11 priorities with the transport concerns of developing countries. Meeting participants issued a set of recommendations that reflect the evolving consensus within the GEF family on how to address urban transport issues within OP11.

3.1 Environmental Issues in the Bank's Urban Transport Strategy

Local Air Pollution

The UTS approaches the environmental dimensions of urban transportation primarily from a local air pollution perspective. It identifies the most damaging air pollutants as lead, fine particulate matter (<PM_{2.5}ug), and, in some cities, ozone. It estimates that more than half a million premature deaths per year in developing countries can be attributed to air pollution, which translates to an estimated cost of 2 percent of GDP. Other problems associated with transport include regional environmental impacts (for example, acid rain), noise, and the division of communities by elevated roads and heavy traffic.

To address the problem of local air pollution, the UTS identifies the following three priorities:

- (i) Elimination of leaded gasoline

- (ii) Replacement of two-stroke by four-stroke motorcycles
- (iii) Elimination or cleaning up of high-mileage gross polluting vehicles.

The UTS emphasizes that technologies alone are not sufficient to deal with local air pollution. Common causes of vehicular pollution in developing countries include fuel adulteration, use of improper lubricants, overloading of vehicles, alteration of engines, driver behavior, and poor vehicle maintenance. Simple inspection and maintenance programs, if designed to minimize the incentives for cheating, can be effective in reducing vehicle emissions. A pilot vehicle inspection and minor tune-up program of 699 vehicles in Dhaka, Bangladesh, found that of the 699 vehicles in the program, tail pipe emissions of carbon monoxide (CO) were reduced in 53 percent of the vehicles, hydrocarbons in 55 percent of the vehicles, and smoke opacity in 72 percent of the vehicles (World Bank 2002a).

The UTS also notes that in many cases improving the operational efficiency of urban transport modes can improve transport performance while reducing local environmental impacts. For example, greater attention to non-motorized transport can improve the efficiency of the urban transportation system and reduce local air pollutants. Similarly, increased use of public transport systems, combined with better traffic management,

can enhance the effectiveness of urban transport systems while mitigating air pollution.

Climate Change

The UTS notes the difficulty of convincing urban transport policymakers in the developing world to prioritize climate change-related interventions. Most policymakers in developing countries are preoccupied with urgent near-term challenges with limited skilled personnel and scarce resources. The UTS therefore recommends the pursuit of options that link GHG mitigation to near-term benefits, such as reducing local air pollution and balance of payments gains associated with more efficient use of imported fuels. In the short term, the UTS proposes that emphasis be placed on policy reforms, such as fuel pricing and taxation. Over the long term, greater attention should be paid to technological changes (including NMT and increased reliance on public transport systems). It also notes that most of the interventions that improve urban road transport systems often reduce GHG emissions (see Table 2).

A recent study by Fulton and Schipper (2002) (see Appendix 6) shows that the majority of the GHG benefits of bus transport are achieved by moving people out of smaller paratransit and private motor vehicles. Moving to advanced bus technologies may produce only marginal additional benefits for global pollutants. Viewed from a cost perspective, the climate change analysis would favor a typical diesel bus over a zero-emis-

Table 2. GHG Emissions from Different Transport Modes

Mode	CO ₂ -equivalent emissions (grams/vehicle-km)	Maximum capacity (passengers)	Average capacity (passengers)	CO ₂ -equivalent emissions (grams/passenger-km)
Pedestrian	0	1	1	0
Bicycle	0	2	1.1	0
Gasoline motor scooter (2-stroke)	118	2	1.2	98
Gasoline motor scooter (4-stroke)	70	2	1.2	64
Gasoline car	293	5	1.2	244
Gasoline taxi car	293	5	0.5	586
Diesel car	172	1.2	1.2	143
Diesel minibus	750	20	15	50
Diesel bus	963	80	65	15
Compressed natural gas bus	1,050	80	65	16
Diesel articulated bus	1,000	160	130	7

Source: Hook and Wright 2002.

sion bus; the cost of the former, according to an IEA analysis, would be about 15 percent of that of the latter (IEA 2002). Local air pollution benefits might provide additional reason for moving to more advanced bus technologies, but as the analysis of GHG emissions shows, the majority of gains from buses would come from the displacement of numerous other vehicles.

Problems of Inadequate Data

There is currently a lack of adequate data on potential GHG savings as well as on the costs of various urban transport measures. Most of the available information is anecdotal or reliant on data from more developed economies with urban characteristics that are fundamentally different from those in developing countries. There is a strong case for supporting activities to improve the quality of data and information on GHG emissions

from urban transport in developing countries.¹

3.2 The GEF’s Operational Program for Sustainable Transport

The initial priorities for OP11 were set out in the program guidance document of the GEF <<<http://gefweb.org>>>. The following six measures were identified for support:

- (i) Modal shifts to more efficient and less-polluting forms of public and freight transport through measures such as traffic management and avoidance and increased use of cleaner fuels
- (ii) NMT
- (iii) Fuel-cell or battery-operated two- and three-wheel vehicles designed to carry more than one person
- (iv) Hydrogen-powered cell or battery-operated vehicles for public transport and goods delivery

- (v) Internal combustion engine (ICE)-electric hybrid buses
- (vi) Advanced biofuels—advanced technologies for converting biomass feedstock to liquid fuels.

According to the GEF, it would finance the following types of activities on an “incremental cost”² basis:

- (i) Integrated strategic urban, land-use, and transportation planning to set out plausible development paths to environmental sustainability.
- (ii) Targeted research on integrating information on country resource endowment with information on the cost-effectiveness of potential applications; on potential costs and benefits of selected measures, including on techniques for estimating fuel savings; and on adaptation to local conditions.
- (iii) Training, capacity-building, and technical assistance for reducing uncertainties about costs, performance, and benefits; for strengthening local capabilities and institutions to operate, manage, maintain, and evaluate eligible sustainable transport measures; and for identifying, planning, implementing, and integrating follow-on projects. Such measures also include institutional strengthening to adopt supportive regulatory frameworks and financial evaluations.
- (iv) Demonstration projects with clear benefits, such as reduced uncertainties about costs, performance, and market

acceptance. Demonstrations can also help with the resolution of institutional issues associated with a new technology and with the development of maintenance and service infrastructure.

- (v) Investment in the most promising applications conforming to OP11 guidance. Cost reductions will be accomplished by promoting technology transfers, joint ventures, and local manufacturing; learning by doing; and achieving economies of scale.
- (vi) Market transformations to achieve full commercialization, including the use of innovative non-grant financing modalities.
- (vii) Dissemination of learning and experience to lead to wider application of sustainable transport measures.³

Overlap with Bank’s Urban Transport Strategy

A comparison of the initial priorities of OP11 and those of the Bank’s UTS (Table 3) reveals that there is the greatest overlap between “Improved operational efficiency of transport modes” in the UTS and the first two priorities of the GEF (that is, “Modal shifts” and “NMT”).

There is some overlap between the GEF’s modal shifts and NMT priorities and the other three elements of the Bank’s UTS, namely (i) structural land-use changes; (ii) better focusing of pro-poor interventions; and (iii) PIF reforms. There is little or no overlap between

Table 3. Overlap Between the Bank’s UTS and Initial OP11 Priorities

		Four Key Elements of World Bank UTS Review			
		(i) Structural land-use changes	(ii) Improved operational efficiency of transport modes	(iii) Better focusing of pro-poor interventions	(iv) PIF Reforms
Priorities of the GEF OP11	(i) Modal shifts				
	(ii) NMT				
	(iii) Fuel-cell or battery-operated 2- or 3-wheel vehicles				
	(iv) Hydrogen- powered fuel cells or battery-operated public or freight vehicles				
	(v) ICE-electric hybrid vehicles				
	(vi) Advanced biofuels				

Key: Minimal overlap— ; Some overlap— ; Maximum overlap— .

the Bank’s UTS and the GEF priorities that focus on advanced technologies (fuel cells, electric/hybrids) and fuels (biofuels).⁴

PIF Measures

An important difference between the Bank’s UTS and the initial priorities outlined for OP11 is the greater emphasis placed on PIF measures in the Bank strategy paper. The UTS argues that such measures not only promote sustainable transportation but also constitute an important prerequisite for the successful deployment of many technical measures. Unfortunately, there is currently a lack of data on the potential GHG savings associated with various PIF measures with respect to transport. Filling this gap would appear to be an important task for the GEF and is con-

sistent with the targeted research objectives of the GEF and OP11.

3.3 OP11 Priorities Recommended by the GEF’s STAP

Given the limited scope of the OP11 proposals received during the first three years and criticism by a number of GEF Council members of the technology-based focus of OP11, the GEF and its implementing agencies asked the STAP to provide guidance on OP11. In response, STAP organized a meeting in March 2002 to discuss ways of broadening the OP11 program toward fulfilling the initial mandate of modal shift and non-motorized transport. In addition to GEF and Implementing Agency representatives, the meeting was attended by international ex-

perts and senior urban transport policymakers from 19 countries.

Participants in the seminar organized by STAP in March 2002 recommended the following four priorities for OP11 for stimulating modal shifts in urban transportation:

- (i) Public rapid transit, which encompasses bus rapid transit (BRT), light rail transit, and trolley electric buses
- (ii) Transport- and traffic-demand management, which includes parking measures, traffic cells, area licensing (restricted zones), and congestion pricing
- (iii) NMT, which encompasses maintaining physically separate NMT networks, traffic calming, strengthening NMT manufacturing and maintenance enterprises, and improving NMT vehicles
- (iv) Land-use planning through regulatory measures (zoning laws) and placing new

public facilities such as schools, hospitals, police stations, and playgrounds in transit-friendly locations).

If one compares these recommendations for OP11 with the urban transport priorities of the World Bank, one sees significantly more overlap than with the original OP11 priorities (Table 4).

STAP seminar participants also emphasized the need for better data and case-study information on the impact the various urban transport interventions on GHG emissions in developing countries. They were particularly interested in seeing GEF-targeted research activities that address the potential of land-use planning in reducing transport-related GHG emissions.

Table 4. Overlap Between the Bank’s UTS and the Revised OP11 Priorities

		Four Key Elements of World Bank UTS Review			
		(i) Structural land-use changes	(ii) Improved operational efficiency of transport modes	(iii) Better focusing of pro-poor interventions	(iv) PIF reforms
Priorities of GEF/STAP for modal shifts to sustainable urban transport modes	(i) Public rapid transit				
	(ii) Transport- demand management				
	(iii) NMT				
	(iv) Land-use planning				

Key: Minimal overlap— ; Some overlap— ; Maximum overlap— .

4.0 PRIORITIES FOR THE WORLD BANK FOR CLIMATE CHANGE MITIGATION IN THE URBAN TRANSPORT SECTOR

How can the World Bank and its client countries make greater use of the Global Environment Facility to support developing countries' priorities for urban transport? This section identifies some of the most promising ways in which the World Bank can help client countries address climate change within the context of urban transport priorities.

The Bank's priorities for urban transport have been outlined in the new strategy paper and have been summarized in the previous sections. In addition to emphasizing the previous goals of improving the efficiency, management, and financial health of urban transport systems, the new strategy underscores the importance of increasing access to public transportation for all citizens, including the poor, and of reducing negative externalities such as air pollution, noise, and traffic accidents. As seen in the previous section (Table 3), the initial technology-based priorities of the GEF's OP11 overlapped to only a limited degree with the emerging urban trans-

port priorities of the World Bank. This lack of overlap, combined with limited knowledge of the GEF and practical experiences among World Bank transport staff, has resulted in a relatively small number of OP11 proposals.

The prospects for additional OP11 projects from the World Bank are improving. Over the past year, there have been a number of new GEF proposals from the World Bank that correspond to the emerging priorities for the GEF, as defined in part by the recommendations of the STAP (Table 4). The following would appear to be some of the promising areas for GEF support and which overlap with World Bank urban transport priorities.

4.1 Modal Shifts to Public Transport

Improving the efficiency and coverage of public transportation is critical for developing countries and is one of the priorities in the Bank's UTS strategy. In addition, provid-

ing efficient public transportation is essential to offset or avoid the high energy use and emissions associated with the growth of private motorized transport in developing countries. Recent studies indicate that transporting people through efficient public transport modes, regardless of the technology, can have a large impact on reducing energy consumption and GHG emissions.

Cost-effective public transport programs such as bus rapid transit (BRT) are examples of a measure with potentially large benefits on local air quality as well as global climate change. There is significant scope for the GEF to support the development of BRT and other cost-effective public transit initiatives in developing countries in which the Bank works. While support for physical investments is possible, more likely areas of support by the GEF would be for:

- (i) Integration within overall transport and regional planning
- (ii) System planning and design
- (iii) Institutional and regulatory capacity building
- (iv) Information and awareness programs for both decision-makers and the public.

Drawing on the experiences in Curitiba and Bogota, other Latin American cities are pursuing BRT with assistance from the World Bank and the GEF. In Mexico City, the GEF is supporting bus corridors that would help integrate buses and the metro and improve

the environmental performance, financial sustainability, and image of public transport in the city. GEF resources are being used for system planning for the bus corridors, for institutional development associated with BRT, and for public awareness. In Peru, the World Bank is assisting the City of Lima with a number of urban transport initiatives, including a new system of segregated bus lanes. The GEF is helping to eliminate pressures on the segregated bus lanes and the public bus system in general caused by numerous old and polluting buses.

4.2 NMT

NMT is an important and often overlooked component of urban transport systems in developing countries. Given the characteristics of NMT—pro-poor, low cost, and relatively easy to implement in a short period of time—it has been highlighted in the World Bank’s urban transport strategy. NMT continues to be a high priority for the GEF.

NMT initiatives have the potential to reduce the carbon intensity of urban (and rural) transport and at the same time providing low-cost transport alternatives to the poor. The local environmental benefits of increased pedestrian and non-motorized transport are also very important in developing country cities. Likely areas for support of NMT by the GEF include:

- (i) Integration of NMT and pedestrian concerns within city and regional urban and transport planning

- (ii) Design and planning of specific NMT components
- (iii) Construction of NMT lanes and pathways
- (iv) Strengthening of NMT manufacturing and maintenance capacity
- (v) Traffic-calming measures to improve the efficiency and safety of pedestrians and NMT
- (vi) Capacity-building for institutions involved in the management and maintenance of NMT systems
- (vii) Information and awareness-raising for decision-makers and the public.

The first full-size OP11 project approved by the GEF was for the Marikina Bikeways Project in the Philippines (see Box 5). Two other World Bank projects, both of which are in Latin America, have requested support from the GEF for NMT components. A project in Santiago, Chile, will promote increased bicycle use through the construction of 40 kilometers of bike lanes (GEF support

Box 5
Marikina Bikeways Project in the City of Marikina, the Philippines

The project is supported by a US\$1.9-million grant from the GEF to the city of Marikina. The GEF component would promote a shift from motor vehicles to NMT, particularly bicycles, by making NMT a safer and more convenient transport mode in Marikina City in metropolitan Manila. Its global environment objective is to slow the growth of transport-related GHG emissions. This would be achieved by shifting transport demand toward NMT modes and maintaining the current demand share served by non-motorized modes. A secondary objective is to demonstrate and publicize the benefits and viability of NMT as an alternative transport mode, so as to encourage replication of this pilot NMT program in other parts of metro Manila, elsewhere in the Philippines, and in other countries.

These objectives will be achieved by constructing, evaluating, and promoting the Marikina Bikeway System (MBS), a 66-km-long network of trails and road lanes specifically designed for NMT, plus bicycle parking and traffic-calming systems. The network will connect residential communities with schools, employment centers, the new metropolitan train station, and other public transport terminals. Provision of these NMT-friendly facilities will encourage the use of NMT modes, and connection with the public transport terminals will promote the combined use of NMT and train or bus for trips between Marikina and the rest of the metropolitan area. The costs and benefits of this pilot NMT initiative will be thoroughly monitored and evaluated and widely disseminated to the World Bank’s client countries and transport specialists.

The MBS will be a component of the broader Metro Manila Urban Transport Integration Project (MMURTRIP), which will be cofinanced by the Government of the Philippines and the World Bank. MMURTRIP’s development objective is to reduce Manila’s traffic congestion and travel times, particularly those experienced by public transport users, the majority of whom are poor. This objective will be achieved through the improvement of street level interchanges between buses, jeepneys, and LRT, and the implementation of effective traffic management measures along major travel corridors.

Source: World Bank.

for 19 kilometers) and implementation of strategies to promote a shift to NMT and to ensure the safety of bicyclists. In Lima-Callao, where the World Bank financed an NMT component in the early 1990s, efforts are under way to overcome barriers to greater bicycle use on the bikeway and in the city as a whole. The request to the GEF includes support for improved safety of the bikeways, extension of the existing network to fill in missing sections and to connect to the public bus system, bike parking and other facilities at bus terminals, a credit program for bicycle acquisition, and a bicycle-promotion campaign.

4.3 Transport and Urban Planning

Energy use for urban transport is determined by a number of factors, not the least of which is the location of jobs and residential housing. Urban planning can have a large impact on transport energy use. In addition, urban transport planning, such as transport infrastructure, and priorities given to public-versus-private transport, can have an effect on the location of businesses and commerce, and where people choose to live.

The GEF is one of the few climate change funding mechanisms that is able to support long-term transport planning activities. Recognizing the importance of land-use planning to transport energy use, OP11 has stated that it is specifically taking a long-term perspective in achieving the associated climate

change benefits. The GEF can support alternative transport and urban planning for the purposes of achieving a less energy-intensive pattern of energy use from the transport sector. Among the types of activities that the GEF is likely to support are:

- (i) Support for studies incorporating sustainable energy themes within urban and regional transport planning.
- (ii) Technical assistance to government agencies (for example, planning and sectoral agencies), non-government organizations, research institutions, and the private sector on integrating sustainable transport solutions into urban and regional plans.
- (iii) Support for incorporating specific themes (for example, NMT) within urban and transport planning.

As noted above, GEF aid can be particularly helpful for planning efforts for public transport and NMT. Support for transport and urban planning has been included in several OP11 proposals submitted to the GEF by the World Bank, including the projects in Mexico City and Santiago.

4.4 Transport-Demand Management (TDM)

Curtailing the demand for urban transport services and, in particular, the demand for private fossil-fueled vehicles, is a key component of climate change mitigation in the urban transport sector. As noted in the Bank's

UTS, it is essential to address urban transport demand in a comprehensive fashion. For example, unless there are alternatives to private vehicles (such as public transit and NMT), physical or price constraints are unlikely to be very effective in curbing use of private vehicles. However, the efficiency of public transit and NMT is also affected to a great extent by the behavior of private vehicles. Measures to limit the demand for private road vehicles (for example, road pricing, parking policies, and fuel and vehicle charges) can not only help improve the efficiency of other modes of transport but also be key components of many cities' plans for environmental improvement. They have climate change benefits as well.

A range of TDM activities can affect vehicle demand and usage. Three of the more important are:

- (i) pricing (for example, road pricing, fuel pricing, vehicle charges).
- (ii) controls on parking (for example, quantity of parking, time and space restrictions, fees).
- (iii) traffic restraint measures (for example, license plate schemes, city center restrictions, HOV lanes, traffic calming).

GEF support for TDM activities has been more limited than for the other activities outlined above. Nonetheless, the justification and principles for GEF support are clear. A case for GEF support can be made where TDM activities facilitate the switch to more

energy-efficient or less carbon-intensive forms of transport, such as public transport or NMT, or can lead to sustainable reductions in the demand for carbon-intensive road vehicles.

A number of transport-demand management measures, such as dedicated bus lanes, limitations on the number of buses allowed to operate in the corridors and for feeder systems, and traffic-management measures designed to ensure the smooth flow of buses and other traffic, are needed in order for BRT systems to operate effectively. The BRT program in Bogota has used a number of TDM measures on private vehicles to ensure the efficiency of TransMilenio (see Appendix 1). There is a similar need for TDM measures to improve the safety and efficiency of pedestrian and NMT systems, such as traffic calming, signage, and limits for on-street motor vehicle parking. The GEF project in Santiago is proposing a number of TDM measures in support of improved bus and NMT systems.

Other TDM measures could be pursued, independent of public transport and NMT systems, with climate change objectives in mind. Examples of the activities that could be supported by the GEF include:

- (i) Studies of the effect of TDM measures on short- and long-term energy use
- (ii) Pilot programs to test feasibility and effectiveness
- (iii) Capacity-building among transport and other agencies responsible for imple-

- menting TDM measures
- (iv) Information-dissemination and awareness-raising campaigns.

4.5 Others

It is not possible to provide a definitive list of the types of activities that could be supported by the GEF under OP11. By design, the GEF is flexible and encourages innovative approaches, and this is especially true for OP11. From the Bank's perspective, however, there are other activities that make sense from an urban transport perspective and that have climate change and local environmental benefits as well.

Regulations and Standards

The establishment and enforcement of environmental regulations can be a way to eliminate the use of old, energy-inefficient, and highly polluting vehicles. This approach is being used in a number of cities in developing countries. There may also be a case for promoting fuel economy standards for individual vehicles and overall fleets (both public and private) as a way of reducing energy consumption and GHG emissions. As with the other activities mentioned above, regulations and standards would be most appropriate as part of an overall package of urban transport measures.

Technology and Fuels

For a variety of reasons, some of which are discussed in section 3, this report does not

mention technology- and fuel-based activities as areas where the World Bank should focus its attention. However, there may be possibilities to assess or test the prospects of new technologies or fuels within the context of a broader package of urban transport activities. The objective of such technology or fuel components needs to be GHG mitigation rather than the mitigation of local pollutants. As such, technologies that promise considerable energy and CO₂ savings could be appropriate (e.g., hybrid buses), while technologies with primarily local environmental benefits (e.g., CNG buses) would not. Additional capital and operational costs are one of the biggest constraints for the introduction of new technologies or fuels in developing countries. Recent experience indicates that the GEF is unlikely to cover the incremental costs of new technologies or fuels. In all cases, the framework (institutional, economic, commercial, cultural) for the introduction of new technologies or fuels needs to be assured in a country-specific context.

4.6 Research Needs

One of the constraints to expanding GEF support for all of the areas mentioned above is the lack of data on energy savings and emission reductions (see Appendix 6). The existence of energy and GHG information from pilot research programs was an advantage of technology-focused projects in the initial years of OP11. As additional OP11

projects are prepared and implemented, these types of data will become more readily available. Nonetheless, there is a need for research on the themes mentioned above, with perhaps the highest priority going to

public transport and NMT programs.⁵ Non-project funding is available from the GEF for targeted research, and it can be pursued by client countries and by the World Bank.



APPENDIX 1

TRANSMILENIO — BOGOTA'S BUS RAPID TRANSIT SYSTEM

As part of a comprehensive urban mobility strategy, the City of Bogota, Colombia, has developed a BRT system called TransMilenio. Bogota is one of the most densely populated cities in the world, with approximately 7 million people living in an area of only 35,000 hectares. Many of the main roadways are heavily congested, and the traffic speed during rush hour is only 10 kilometers per hour. The use of private cars is a major cause of the congestion. Although approximately 71 percent of motorized person trips are made by bus, 95 percent of road space is used by private cars, which transport only 19 percent of the population.

TransMilenio is part of the strategy implemented to reduce congestion in the city by reducing reliance on private cars. It consists of the following main components:

- Infrastructure to reduce traffic congestion which is the responsibility of the public sector (exclusive lanes, stations and terminals, access ways, parking lots, and maintenance shops)
 - An efficient operating system (operation companies, buses, and employees) run by the private sector
 - A transparent fare collection system (equipment, card-based, and fiduciary management) run by the private sector
 - A permanent public institution in charge of planning, operation, and control.
- Some features of the system are as follows:
- People are transported in articulated buses that hold up to 160 passengers.
 - There are stations every 500 meters and terminals and interchange stations at the end of each line so that passengers can continue their trips using feeder buses (40- to 80-passenger capacity) without paying an extra fare.
 - Each articulated bus has a GPS (global positioning system) connected by satellite to a control center, where the frequency, position, and speed are controlled.

- Fares are paid before entering the stations using a card system.
- The concessionaires for the operation include operators already providing bus services and domestic and international investors, while the feeder bus service is contracted out to existing transport companies.

The first stage of the system, partially under operation, comprises 470 articulated buses and 41 km of segregated busway. The total cost of the first stage was US\$213 million for the fixed infrastructure plus US\$115 million for the buses, which were financed by the private operators. The system is managed by a new public company, TransMilenio S.A., funded by a 3 percent levy on the ticket sales. The company operates a control center that supervises service and passenger access. As of June 2002, ridership on TransMilenio was 680,000 passengers per day, at a ticket cost of US\$0.36, and the system operated without subsidies. Stages II and III are proposed to expand the system to include 22 corridors that could meet the demand of about 85 percent of the trips made in Bogota.

In addition to exclusive busways, the City of Bogota has 230 km of bike lanes with plans to increase this to 350 km; expanded sidewalks; about 1,100 new parks; and a 17-km pedestrian zone. Among the TDM measures instituted are forbidding private cars to operate in Bogota during the morning and evening peaks (such cars are identified by the last four digits of their license plate). Parking fees were increased by 100 percent, and gasoline taxes increased by 20 percent. Bollards were built to prevent people from parking illegally on the sidewalk. A key promotional measure is "car-free day," held once in a year on a week day, and car-free Sundays on particular roads.

The combination of the BRT, TDM, and NMT measures resulted in the reduction of private cars and taxi trips from 19.7 to 17.5 percent. Public transit passenger trips increased from 67 to 68 percent of the total trips, and travel time was reduced by 32 percent.

Sources: World Bank 2002; Hook and Wright 2002; GEF 2002a; Ardila and Menckhoff 2002.



APPENDIX 2

THE MASS TRANSIT SYSTEM IN CURITIBA, BRAZIL

The setting up of the mass transit system in Curitiba began with preserving the city center by developing a slow traffic ring integrated with a series of fast routes between the main nodal points of the city. This eliminated the need for entrance into the central business district, which was then reserved for pedestrians and local traffic.

The first exclusive bus lane, opened in 1974, was 20 km long and linked the north and southern parts of the city. The exclusive bus lanes enabled the buses to maintain a speed of 30 kph. This north–south express axis was linked to the other parts of the city by conventional buses. In the following five years, mass transport terminals and an east–west line were built.

In 1980, a single fare was introduced, which meant that the shorter journeys subsidized the costs of the longer ones. This enabled the city residents in the outer areas, who were

generally the lower-income groups, to be subsidized. In addition, circular lines composed of four rings were added to the branch system, which integrated to cover the whole city. The fuel crisis of the early 1980s played a crucial role in the popularity of the mass transit system for the private car owners, who found that public transportation was cheaper, relatively convenient, and fast.

In 1981, articulated buses with a capacity of 150 passengers were introduced. The buses were built in a Volvo plant in Curitiba. Riders preferred these buses because they were, on average, 10 times cheaper than trams and 100 times cheaper than underground trains.

By 1990, the system had articulated buses with capacity of 170 passengers per bus and could move 10,000 to 14,000 passengers per lane per hour. In 1991, non-stop express services were introduced. These buses had a smaller capacity (100 passengers) and could

therefore maintain a high average speed. In addition, boarding stations at the same level as the buses were constructed along the direct lines. This was intended to speed the boarding and alighting of passengers. To further improve the boarding, fares were paid at the entrance of the station. A lift was added for disabled passengers. The whole design was modeled on that of an underground rail system. This system became very popular,

and in 1992, 270-person, bi-articulated buses were introduced.

Fuel consumption in Curitiba is now 25 percent less than in comparable cities in Brazil, and around 70 percent of trips per day are made with public transport.

Sources: Lerner 2000; Menckhoff 1999; <<<http://www.ingp.org/general/meetings/curitiba.htm>>>.

APPENDIX 3

ESTIMATED ENERGY AND GHG REDUCTIONS OF VARIOUS TRANSPORT OPTIONS

<i>Measure</i>	<i>Savings/Benefits</i>	<i>Reference</i>
Public Rapid Transit Systems		
BRT system (Bogota, Colombia)	Air pollutants reduced by 40% Travel time reduced by 32% ¹	World Bank. 2002b. <i>Cities on the Move--A World Bank Urban Transport Strategy Review: Private Sector Development and Infrastructure</i> . Washington, D.C. GEF. 2001. "Project Brief: Mexico-- Introduction of Climate-Friendly Measures in Transport"
Combination of BRT, TDM, and NMT measures (Bogota, Colombia)	Reductions of 318 MT of CO ₂ , SO ₂ by 40%, and PM by 10%, in 2001 as compared to 1997 Reduced private car taxi trips from 19.7% to 17.5% of trips Bike trips increased from 0.5% to 4% of trips	Hook, W., and L. Wright. 2002. "Reducing GHG Emission by Shifting Passenger Trips to Less-Polluting Modes." Background Paper for the Brainstorming Session on Non-Technology Options for Stimulating Modal Shifts in City Transport Systems held in Nairobi, Kenya. STAP/GEF. Washington, D.C.
Trolley bus rapid transit system (Bogota, Colombia)	Ridership per bus rose from 312 to 1,807 passengers per day ²	GEF. 2001. "Project Brief: Mexico - Introduction of Climate Friendly Measures in Transport."
Exclusive busways (Lima, Peru)	6.0 million bus kilometers saved per annum ³	GEF Project Document. "Public Transport Improvement Program in Lima, Peru." << www.gefonline.org >>.
Traffic-Demand Management		
Computerized control of traffic signals (Singapore)	Average vehicle travel speed rose from 4 km/hr to 6 km/hr Energy saving of 307GJ per weekday	Fwa, T. F. 2002. "Transportation Planning and Management for Sustainable Development--Singapore's Experience." Paper presented at a Brainstorming Session on Non-Technology Options for Stimulating Modal Shifts in City Transport Systems held in Nairobi, Kenya. STAP/GEF. Washington, D.C.
Optimal road pricing based on congestion charging (London, UK)	Reduction of emissions - CO: 42% - VOCs: 38% - NOx--21% - PM--27% - CO ₂ --37%	Maddison, D., D. Pearce, O. Johansson, E. Calthrop, T. Litman, and E. Verhoef. 1996. <i>The True Costs of Road Transport</i> . London: Earthscan Publications Ltd.
Congestion pricing of the Namsan Tunnels (Seoul, Korea)	- Reduction of 34% peak passenger vehicle volume - Average travel speed increased by 50% (from 20kph to 30kph)	World Bank. 2002b. <i>Cities on the Move--A World Bank Urban Transport Strategy Review: Private Sector Development and Infrastructure</i> . Washington, D.C.
Fuel pricing and taxation	15%--20% for vehicle operators	Martin, D., D. Moon, S. Collings, and A. Lewis. 1995. <i>Mechanisms for Improved Energy Efficiency in Transport</i> . Overseas Development Administration. London, UK.
Promoting one car-free day per week (Mexico)	Reduction in private car use (modal share reduced from 25% to 17%)	Pointec Inocsa Stereocarto, Urban Public Transport Systems Integration and Funding, Paper prepared for the World Bank urban transport strategy, 2001, Washington, DC.

Climate Change Mitigation in the Urban Transport Sector

Measure	Savings/Benefits	Reference
Demonstrations and information dissemination programs	10% energy savings from users in the target subsector	Martin, D., D. Moon, S. Collings, and A. Lewis. 1995. <i>Mechanisms for Improved Energy Efficiency in Transport</i> . Overseas Development Administration. London, UK.
Fleet management in form of training programs and equipment purchase for engine maintenance -Operating procedures such as monitoring and targeting programs -Training of drivers and incentive schemes	5%–10% energy savings per vehicle 20% energy savings per vehicle 5%–10% energy savings for bus operators	Martin, D., D. Moon, S. Collings, and A. Lewis. 1995. <i>Mechanisms for Improved Energy Efficiency in Transport</i> . Overseas Development Administration. London, UK.
Travel blending/social marketing (Santiago and Australia)	17% reduction in car trips 23% reduction car driver km 17% reduction in travel time 6% decrease in auto use ⁴ Increase in public transport trips from 6% to 7% Increase in cycling from 2% to 4%	Hook, W., and L. Wright. 2002. "Reducing GHG Emission by Shifting Passenger Trips to Less-Polluting Modes." Background Paper for the Brainstorming Session on Non-Technology Options for Stimulating Modal Shifts in City Transport Systems held in Nairobi, Kenya. STAP/GEF. Washington, D.C.
Non-Motorized Transport		
Promotion of non-motorized transport	100% energy savings for substituted trips	Martin, D., D. Moon, D., S. Collings, and A. Lewis. 1995. <i>Mechanisms for Improved Energy Efficiency in Transport</i> . Overseas Development Administration. London, UK.
Bicycle network (Delft, The Netherlands)	Modal increase in bicycle usage from 40% to 43%	Interface for Cycling Expertise, 2000. <i>The Significance of Non-Motorized Transport for Developing Countries: Strategies for Policy Development</i> . Utrecht, The Netherlands. << www.cycling.nl/publications/sign_non_mot_transport.pdf >>
Modern Indian rickshaws	3.2 tons of CO ₂ emission reduction per day	Hook, W. and L. Wright . 2002. "Reducing GHG Emission by Shifting Passenger Trips to Less Polluting Modes." Background Paper for the Brainstorming Session on Non-Technology Options for Stimulating Modal Shifts in City Transport Systems held in Nairobi, Kenya. STAP/GEF. Washington, D.C.
Bicycle path network (Tamale, Ghana)	The 60-km bikeway resulted in bicycles accounting for 65% of transport trips in Tamale	Moving the Economy, 2002. "Mobility in the Developing World" (Case Studies) << www.movingtheeconomy.ca >>
Land-Use Planning		
Land-use planning combined with traffic management	20%–30% energy savings for bus operators	Martin, D., D. Moon, S. Collings, and A. Lewis. 1995. <i>Mechanisms for Improved Energy Efficiency in Transport</i> . Overseas Development Administration. London, UK.
Area licensing scheme (Singapore)	1.043GJ per day energy savings Total vehicular traffic reduced by 50%; private traffic reduced by 75% Travel speed increased from 20 to 33 kph, saving time and energy while engines were idling	Fwa, T. F. 2002. "Transportation Planning and Management for Sustainable Development—Singapore's Experience." Paper presented at a Brainstorming Session on Non-Technology Options for Stimulating Modal Shifts in City Transport Systems held in Nairobi, Kenya. STAP/GEF. Washington, D.C.

Notes:

1. The reduction was on the corridors.
2. A total of 1,807 passengers per day were transported on the TransMilenio, 312 passengers per day were transported under the traditional system.
3. These were results of a pilot program.
4. These were results of an immediate decrease in auto use of the 380 households targeted. There was an additional 1% decrease after 12 months.

APPENDIX 4

ESTIMATED COSTS OF VARIOUS TRANSPORT OPTIONS

<i>Transport option</i>	<i>Estimated cost (US\$)</i>	<i>Location</i>
Bicycle	50 per bike	
Busway (infrastructure only)	1.5 million per km	
Trolley bus rapid transit and associated infrastructure	5 million per km ¹	Quito, Ecuador
BRT and associated infrastructure	2.5 million per km	Quito, Ecuador
Bus rapid transit and associated infrastructure	8 million per km ²	Bogota, Colombia
LRT	15–30 million per km	
At-grade metro	15–30 million per km (2000 prices)*	
Elevated metro	30–75 million per km (2000 prices)*	
Underground metro	60–180 million per km (2000 prices)*	
MRT	114–133 million per km (1998 prices)	Hong Kong
MRT	46 million per km (1998 prices)	Singapore
LRT at grade	27 million per km (1998 prices)	Manila
LRT at grade	42 million per km (1998 prices)	Kuala Lumpur

Note: * Estimated cost of metros in Asia in 2000.

1. Estimate is inclusive of 54 trolley buses and their electric system (cost \$US46.3 million); two terminals, 11.2 km of exclusive bus lanes and 39 bus stops (cost \$US7 million); signal system (cost \$2.3 million); and ticketing system (cost \$2 million), which totals \$US57.6 million, or about \$US5.1 million per km.

2. Estimate includes 32 km of busways, 470 articulated trunk buses, and 1,000 feeder buses.

Source: Fox 2000.

Vehical Technologies

<i>Propulsion technology</i>	<i>Cost per vehicle (US\$)¹</i>
Diesel	30,000–100,000 ²
Clean diesel/trolley	100,000–250,000
CNG, ³ LPG ⁴ bus	150,000–350,000
Hybrid electric bus	200,000–400,000
Fuel-cell bus	1.0–1.5 million
Metro rail car	1.7–2.4 million

Notes:

1. Cost estimates provided are for nonarticulated buses.
2. According to Fulton (2001), secondhand buses in developing countries will cost US\$10,000–40,000, while new diesel buses produced by indigenous bus companies in developing countries cost US\$30,000–75,000. If the latter buses meet Euro II standards, then they would cost US\$100,000–150,000. In North America, a typical diesel costs between US\$250,000 and 275,000, while standard OECD Euro II diesel buses cost between US\$180,000–350,000.
3. CNG buses produce 60% to 90% less CO, up to 86% less PM, and up to 58% less NO_x than diesel buses (Alternative Fuels Data Center 2002).
4. LPG buses produce 40% to 60% less CO than diesel buses.

Sources: GEF 2002b, World Bank 2002b.

APPENDIX 5

INVESTMENT COST, CARRYING CAPACITY, AND CO₂ EMISSIONS

Technologies

<i>Technology</i>	<i>Cost per unit (US\$)</i>	<i>Maximum number of passengers¹</i>	<i>CO₂-equivalent emissions (gram/passenger/km)</i>
Bicycle	50	2	0
Diesel bus	30,000–100,000	80	15
CNG bus	150,000–350,000	80	16
Fuel-cell bus	1.0–1.5 million	80	0

Sources: GEF 2002; World Bank 2002b; Hook and Wright, 2002.

Transport Systems

<i>Networks</i>	<i>Cost per kilometer (millions US\$)</i>	<i>Maximum capacity (passengers per hour per direction)</i>	<i>Reduction in CO₂ emissions</i>
Bicycle ways	0.016– 0.0231	15,02	100%
BRT	1.5–5.0	10,000–20,000 ²	318 metric tonnes reduction in CO ₂ per day in 2001 compared with 1997 levels ³
LRT	15–30	10,000–12,000	-
Metro		Over 60,000	-
- At grade	15–30		
- Elevated	25–80		
- Underground	60–180		

Notes:

1. Figures for buses refer to the nonarticulated.
2. Capacity is higher depending on the whether the busway is a two- or four-lane system. For example, in Bogota, Colombia, the system can move 35,000 passengers per hour per direction on a two-lane system.
3. Based on estimates carried out in Bogota, Colombia.

Sources: Fox 2000.

Technology Cost Estimates

Category	Bus cost (thousands US\$)	Other costs
Secondhand bus in developing countries (conversions from diesel trucks), seating 25–40	10–40	-
New diesel bus produced by indigenous bus companies in developing countries	30–75	-
New diesel bus produced in developing countries by international bus companies that meet Euro II	100–150	Some retraining costs and possibly higher spare parts costs
Standard OECD Euro II diesel bus	180–350	-
Diesel with advanced emissions controls	5–0 (more than comparable diesel bus)	If low-sulfur diesel, up to 10 cents per liter higher fuel cost (for small imported batches)
CNG, LPG buses	25–50 (more than comparable to diesel bus)	Fuel infrastructure costs could be up to several million US\$ per city
Hybrid electric buses (on a limited production basis)	100–150 more than comparable diesel bus (less in DCs)	Significant costs for retraining, maintenance, and spare parts
Fuel-cell buses (on a limited production basis)	1,000 (1 million US\$) more than comparable to diesel buses, even in LDCs at this time.	With up to US\$5 million per city for refueling infrastructure and other support-system costs

Note: The range of prices includes transit buses in Europe and North America. Buses in Europe are generally less expensive than those in North America, with the prices in Europe for nonarticulated buses generally below US\$275,000.

Source: Fulton 2001.

Emission Benefits of Adding One Bus to an Urban Transport System¹

(percentage reductions relative to displaced vehicles)

	Road space	Fuel use (CO ₂)	HC	CO	NO _x	PM
<i>Percentages</i>						
Optimistic Scenario²						
Standard diesel bus	-92	-72	-99	-97	-66	-83
Euro II bus	-92	-72	-100	-100	-66	-96
Euro IV bus	-92	-72	-100	-100	-93	-98
Zero-emissions bus	-92	-78	-100	-100	-100	-100
Pessimistic Scenario³						
Standard diesel bus	-39	+50	+68	+46	+85	+41
Euro II bus	-39	+50	-60	-77	+85	-65
Euro IV bus	-39	+50	-92	-94	-63	-86
Zero-emissions bus	-39	+20	-100	-100	-100	-100

Notes: 1. The riders on the bus are from other modes; therefore, a certain number of other vehicles are “displaced” and do not make the trips they would have otherwise made. Assumptions are made on how many passengers other vehicles typically carry, the road space they required, and emissions per kilometer for each vehicle type for a “typical” city.

2. For the optimistic scenario, a standard polluting bus carries the same number of passengers at 92 percent less road space, uses 72 percent less fuel and thus creates 72 percent less emissions and 99 percent fewer emissions of pollutants. The difference in the bus technology chosen is overshadowed by the total reductions achieved through vehicle substitution.

3. For the pessimistic scenario, the standard bus only results in major reduction in available road space that would have been occupied by the 30 commuters in other modes by almost a half. However, the cleaner buses achieve significantly higher emission reductions than the standard bus does.

Source: Fulton and Schipper 2002.

Optimistic Scenario

Assumes an additional bus that accommodates 80 seated passengers (120 standing passengers) is introduced in the system and operates with an average of 60 riders over the course of the day. The 60 passengers are assumed to have shifted from other modes (that is, 20 from two- or three-wheel vehicles with two-stroke engines, 10 from two- or three-wheel vehicles with four-stroke engines, and 10 each from private cars or taxis; small

buses, minibuses, or paratransit; and non-motorized modes).

Pessimistic Scenario

Assumes the additional bus introduced in the system carries an average of 30 passengers. These passengers are assumed to have shifted from smaller buses, minibuses, or paratransit (20 passengers) and non-motorized (10 passengers) modes only.

NOTES

1. A World Bank report, "Flexing the Link between Transport and Greenhouse Gas Emissions," states that "a careful disaggregated approach to measuring transportation activity, fuel use, and emissions is a vital first step in successful GHG restraint" (Schipper and Lilliu 1999).
2. Incremental costs" are the additional costs needed to achieve global environmental benefits for a GEF activity compared with the baseline.
3. GEF. 1999. "Operational Program Number 11: Promoting Environmentally Sustainable Transport."
4. The Bank's UTS (World Bank 2002b) makes direct reference to some of these technologies for developing countries:

"Whatever the environmental balance, the market attractiveness of electric-powered transport depends, as in the case of other fuels, on its economic attractiveness in terms of overall cost and convenience. At present, the economics of electric vehicles are far from favorable."

"It is unlikely, however, that they [fuel cell vehicles] will have early applications in developing countries."

"True biofuels (i.e., those without substantial fossil fuel use hidden in harvesting and processing) would give a real reduction in GHG emission. But these are still elusive in cost competitiveness with gasoline and diesel."

5. One obvious research topic is the TransMilenio program in Bogota, Colombia. While not a GEF project, this program has reported significant energy savings from which GHG emissions reductions can be calculated. Because the TransMilenio program involves a number of measures, including BRT, it is important to assess the relative contribution of various activities, or at least the measures necessary to the success of the overall program, to energy savings.

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World Bank-GEF Anchor
Global Environment Facility Coordination Team
Environment Department
THE WORLD BANK
1818 H Street, NW
Washington, D.C. 20433, USA
Telephone: 202.473.1816
Fax: 202.522.3256
Email: GEOnline@worldbank.org
Web: www.worldbank.org/gef