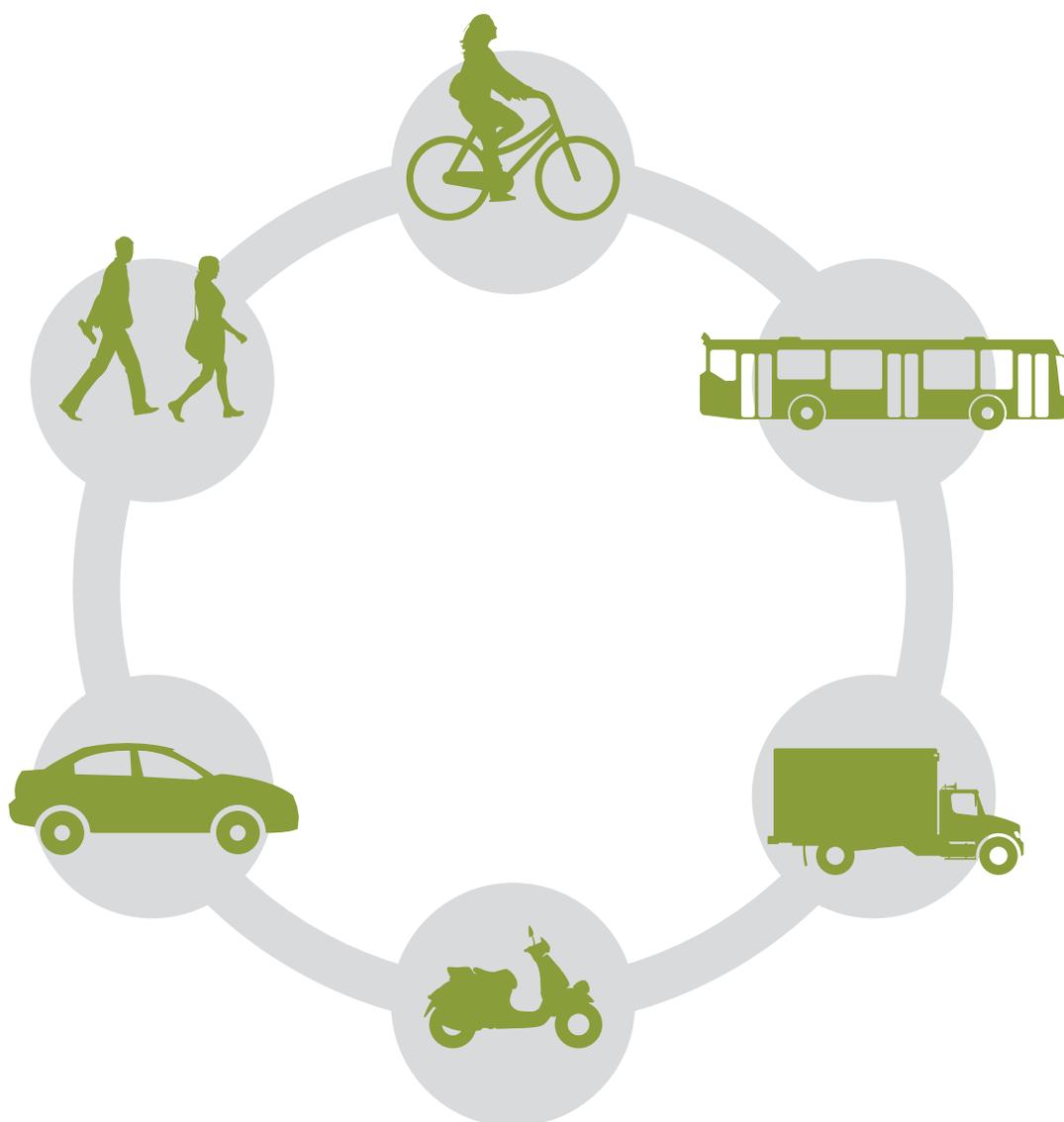


MITIGATION STRATEGIES *and* ACCOUNTING METHODS *for*

Greenhouse Gas Emissions

from TRANSPORTATION



Inter-American Development Bank

MITIGATION STRATEGIES *and* ACCOUNTING METHODS *for*
Greenhouse Gas
Emissions
from TRANSPORTATION

Inter-American Development Bank
Regional Environmentally Sustainable Transport

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Preface

Over the past several decades, urban areas in the Latin American and Caribbean (LAC) region have been experiencing increased economic productivity and an explosion in population growth. Such rises in productivity and employment opportunities are attracting rural area dwellers into cities. From 2000 to 2010, per capita incomes in LAC countries rose by nearly 50 percent, while in some of these countries, motor vehicle numbers have also increased rapidly. Today, LAC is the most urbanized region in the developing world with approximately 80 percent of the population living in urban clusters of large cities marked by sprawling suburbs and exurbs. With such rapid population growth and to support the increases in productivity and competitiveness, LAC cities strive to provide passenger and goods mobility. However, such transportation infrastructure provision presents a significant challenge: to maximize economic productivity and growth, while minimizing the negative environmental and social impacts.

As population and income grow in LAC countries, the urban footprint tends to expand horizontally, and, in some cases, in an uncontrolled manner. This expansion is very often characterized by an increase in the average distance traveled and often creates the need for ever-faster modes of transportation for goods and passengers. Such growth patterns pose significant costs on society and the environment, due to longer trip distances that result in an overall increase in travel costs and use of carbon-intensive modes of transport.

The Regional Environmentally Sustainable Transport Strategic Area at the Inter-American Development Bank, launched its REST Action Plan (2012-2014), to contribute in mitigating Greenhouse Gas (GHG) emissions from the transport sector. The Action Plan provides to country member institutions, planners, and practitioners the necessary knowledge and appropriate tools to mitigate negative impacts related to economic, social, and environmental sustainability in the LAC region, while simultaneously promoting economic growth and productivity.

This document, which is based on the **conceptual framework of the REST Action Plan, provides a list of 11 transport strategies containing 39 innovative GHG reduction measures in the transport sector, applicable to LAC cities. These measures are based on the Avoid-Shift-Improve paradigm for sustainable transport** and include both passenger and freight movement solutions, guidance on implementation costs and difficulty levels, and GHG reduction impacts.

This document has been the foundation for identifying priority topics on urban sustainable transport at the IDB transport division. The Bank is committed to generating knowledge products, technical guides, and regional events, all supporting sustainable transport in LAC, as well creating institutional capacity and providing technical assistance to member countries through the different lending mechanisms and technical cooperation funds.

Néstor H. Roa

Transport Division Chief

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List of Abbreviations

ADB	Asian Development Bank	HFCs	Hydrofluorocarbons
ASI	Avoid-Shift-Improve	IDB	Inter-American Development Bank
ASIF	Activity-Structure-Intensity-Fuel	IPCC	Intergovernmental Panel on Climate Change
ATM	Active Traffic Management	ITS	Intelligent Transportation Systems
BAU	Business as Usual	IVE	International Vehicle Emissions Model
BEF	Baseline Emission Factor	ITDP	Institute for Transportation and Development Policy
BRT	Bus Rapid Transit	LAC	Latin America and the Caribbean
CAF	Corporación Andina de Fomento	LPG	Liquefied Petroleum Gas
CBD	Central Business District	LRT	Light Rail Transit
CDM	Clean Development Mechanism	LUZ	Larger Urban Zone
CFCs	Chlorofluorocarbons	LULUCF	Land Use, Land-Use Change and Forestry
CH₄	Methane	MOVES	Motor Vehicle Emission Simulator
CNG	Compressed Natural Gas	MRT	Metro Rail Transport
CO	Carbon Monoxide	MRTS	Mass Rapid Transit System
CO₂	Carbon Dioxide	MRV	Measurement, Reporting and Verification
CO₂e	Carbon Dioxide Equivalent	NAMA	Nationally Appropriate Mitigation Action
COE	Certificate of Entitlement	MtCO₂e	Million Metric Tons of Carbon Dioxide Equivalent
COPERT	Computer Programme to Calculate Emissions from Road Transport	NMT	Non-Motorized Transport
CTF	Clean Technology Fund	N₂O	Nitrous Oxide
EPA	Environmental Protection Agency	NO_x	Nitrogen Oxides
ERP	Electronic Road Pricing	PEMS	Portable Emissions Measurement System
GCF	Green Climate Fund	PKM	Passenger-Kilometer
GEF	Global Environment Facility	PPP	Public-Private Partnership
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit	TAMT	Transport Activity Measurement Toolkit
GHG	Greenhouse Gas	TDM	Travel Demand Management
GPS	Global Positioning Systems		
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit, now GIZ		
GWP	Global Warming Potential		
HDT	Heavy-Duty Truck		



TEEMP	Transport Emissions Evaluation Models for Projects
TKM	Tonne-Kilometer
TOD	Transit-Oriented Development
TRANUS	A Specific Integrated Transportation and Land use Model
UNFCCC	United Nations Framework Convention on Climate Change
VKM	Vehicle-Kilometer
VRT	Vehicle-Kilometer Traveled
VQS	Vehicle Quota Systems



Part 1

Executive Summary

Introduction

Objective of this monograph

Rising incomes in Latin America and the Caribbean (LAC) portend rising use of motor vehicles, with attendant challenges to manage traffic congestion, air pollution, energy security, and global warming, as well as growing disparities in access to opportunities between those who have cars and those who do not. International concern regarding the effects of climate change is leading to the creation of mechanisms to promote transport initiatives that reduce greenhouse gas (GHG) emissions. In addition, there is an increasingly widespread interest in more sustainable transport strategies that not only reduce GHG emissions but also improve air quality and safety while at the same time providing access and supporting mobility and economic development.

This monograph is intended to assist planners in LAC in understanding how to assess the GHG emissions reduction benefits of sustainable transport projects, policies, and strategies. The document should aid planners accessing climate finance to support sustainable transport initiatives, as well as to assist evaluators in understanding and measuring GHG benefits of proposed investments. While the focus of the document is on measuring GHG benefits, many of the methods discussed are broadly useful for understanding other important social benefits including air pollution and traffic congestion reduction, fuel savings, increased traffic safety, and access to opportunities across the income spectrum.

This document is especially intended for use by planners who have background in transportation project and

program implementation and evaluation, but who may not be completely familiar with the requirements and methods for evaluating GHG emissions impacts. The document includes the following:

- » An overview of sustainable low-carbon transport strategies and how they affect GHG emissions;
- » A review of existing climate finance mechanisms and their specific requirements for measuring, reporting, and evaluation; and,
- » An introduction to existing tools and methods to support GHG impact evaluation for transport projects and programs.

The report emphasizes strategies in the passenger transport sector but also includes freight strategies and methods. The primary focus is on strategies that relate to mode shifting, travel demand management, transport operations, and vehicle technology.

Evaluation requirements for climate finance mechanisms vary widely and demand a wide array of approaches to evaluate GHG emissions and impacts over various spatial and temporal scales. This report does not provide a complete guide to each and every approach, or an in-depth review of each type of transport intervention, but seeks to provide the reader with relevant information to choose the appropriate method and interventions for the context and challenges at hand.

The methodologies to support GHG evaluation discussed here range from simple sketch analysis tools – most useful for places that lack good local data and evaluation capacity – to state-of-the-art and state-of-the-practice analysis methods that require significant ongoing investment in

both monitoring and institutional capacity. The latter are an important foundation supporting development of high performance, sustainable and modern mobility systems, but are not pre-requisites to advancing towards more sustainable transportation.

Urgency of the problem being addressed

As LAC modernizes and develops, trends suggest that this will be accompanied by increasing ownership and use of motor vehicles. If present trends continue, LAC will probably approach Europe's level of motorization of the 1960s by 2030, but with far more urban regions with populations over five million than Europe had in the 1960s or at present. The region's car ownership, car use, and level of emissions from car use are higher than would be expected based on population and gross domestic product (GDP) levels. High motorization rates in LAC are encouraged by a combination of factors including rising GDP per capita, a downward trend in the price of automobiles, more dispersed urban development patterns, and cheap or subsidized fuel. Motorization in LAC initially consisted of 4-wheeled vehicles for transport of passengers and goods. Recently the number of motorcycles has also started to increase rapidly, initially in major cities but now also in second and third tier cities. Rapid growth in freight transport also plays a large and increasing role in LAC's transport GHG and air pollutant emissions.

There is an urgent need to replicate and scale up sustainable low carbon transport policies and activities in the region. In recent years, the transportation community in LAC has been trying to come to terms with the imminent breakdown of urban transport systems in LAC cities due to the seemingly unstoppable rapid growth in private motorization. There is a growing awareness

of the need for policies, backed up with appropriate financing mechanisms, which can reverse the trend of unsustainable growth of private motorization. Furthermore the same transportation community is also challenged to respond to the fact that transport is not only the second largest contributor to GHG emissions in LAC, but that it is also the fastest-growing sector. The combination of these effects represent the disparate benefits and burdens brought by rapid motorization, which yield sharp inequality of access to opportunities and large damage to public health and safety that specifically harms the economically disadvantaged.

To reverse the trend of increasing GHG emissions and overall unsustainability of the transport sector in LAC, developing countries should aim for a decoupling of economic and social development from transport-associated GHG emissions. Such decoupling is increasingly observed in more advanced Asian, European, and North American economies. The amount of GHG emissions per person or ton of freight is related to the number of kilometers driven, how many people (or cargo) are transported in a vehicle, and how fuel efficient the vehicle is. The reduction of GHG emissions from transport needs to address all these components and can be best achieved by adopting the so called "Avoid-Shift-Improve" (ASI) approach which combines measures aimed at:

Avoiding or reducing motorized kilometers traveled that do not serve a productive goal by efficiently integrating land use and transport and improving logistics and communications;

Shifting travel to, or sustaining the modal share of the most efficient modes (typically non-motorized and public transport for passengers; rail, inland waterways, and well-run trucking and intermodal logistics services for freight transport) by strengthening the attractiveness and viability of these modes of travel and discouraging less efficient modes; and,

Improving existing forms of motorized transport (i) through technological improvements and innovations to make vehicles, engines and fuels less carbon-intensive, and (ii) by managing transport network operations for peak efficiency, for example through strategies to improve public transport system management and freight logistics systems.

The Inter-American Development Bank (IDB) is in a privileged position to become a key player in the mitigation of climate change, through the promotion of sustainable transportation in LAC. To date IDB's investment portfolio on land transportation, like other multilateral development banks, has been heavily focused on financing roads, with a modest percentage of investment directed to urban transport and freight rail. Such trend is illustrated by Figure 1, showing the share of IDB transport-related funding by mode 2005-2010.

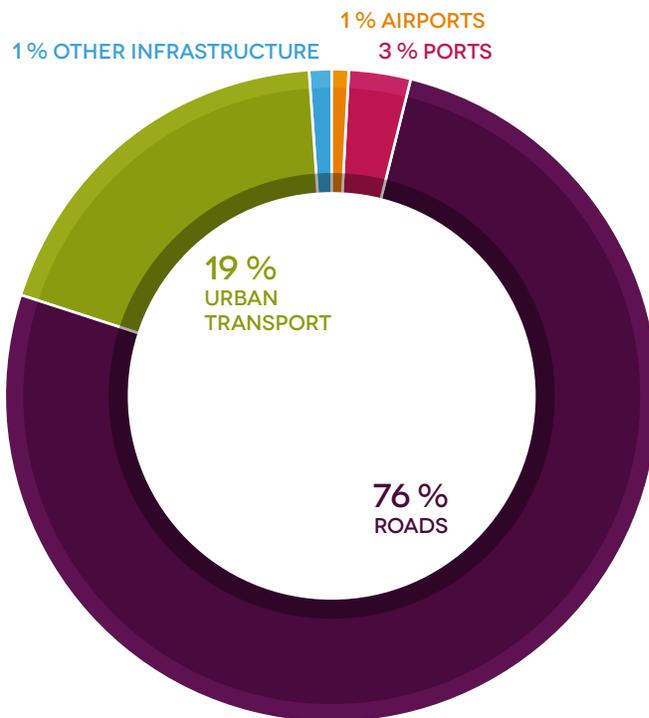
There is a great potential for expanding IDB's share of investments in sustainable transportation, based on its presence in 26 borrowing member countries throughout the region and on its expertise. The Bank's policies on the environment and safeguards, transportation, housing, and urban issues, as well as the Sustainable Energy and Climate Change Initiative, are all aligned with the move towards a greater share of sustainable transportation projects. In addition, under the framework of the IDB's Ninth Capital Increase, the Bank has committed

to substantially increase the volume of lending and technical assistance operations related to climate change, renewable energy, and environmental sustainability.

To implement sustainable transport strategies, it is helpful for planners, consultants, and IDB staff to have ready access to sound appraisal methodologies to evaluate GHG impacts and mitigation strategies. This monograph is designed as an initial resource towards that end. Application of this resource in the development of sustainable mobility plans for several Latin American cities will help reveal the challenges and opportunities for GHG mitigation and appraisal related to transport systems investments and policies.

INTER-AMERICAN DEVELOPMENT BANK TRANSPORT INVESTMENT 2005-2010

(figure 1)



Climate Finance and Transportation

Climate change is a key concern for many countries and financial institutions. Recent efforts by governments and institutions such as the IDB have focused on using financing tools to reduce GHG emissions, especially in developing economies. Although the total value of climate finance is much smaller than conventional financing sources for developing country transportation investments, these instruments are often used to provide incremental benefits that will “tip the scale” for projects to move towards low carbon interventions rather than less sustainable alternatives. Generally, two types of financing exist to support emissions reductions:

- » Emissions trading, also known as “**carbon finance**” and,
- » Funding for climate change mitigation activities, known more broadly as “**climate finance**”.

The first comes from carbon markets like the Clean Development Mechanism (CDM) or voluntary carbon markets and is tied directly to actual levels of carbon emission reductions. The second comes from sources such as the Clean Technology Fund (CTF) and the Global Environment Facility (GEF), through institutions such as the IDB and World Bank, for infrastructure, technology or other projects that include an element of GHG emissions reduction. Climate finance may be further identified as coming from **multilateral sources** (where funding is provided by international donors through an international institution), and **bilateral sources**, where funding is given by one country to another country.

Multilateral and bilateral funds and carbon markets in existence as of 2011 that are potentially available for use for transport projects in LAC countries are identified in Table 1. Of these, CDM, GEF, CTF, and the Japanese Fast Start Finance Initiative have been the largest sources to date. Table 1 also shows total funding allocated since the fund’s establishment, although only a small fraction of this funding has been allocated to transport projects. The landscape of climate finance continues to evolve and new sources may become available, such as the Green Climate Fund (GCF) formally established at the United Nations Climate Change Conference in Durban, South Africa in December 2011. In addition to the sources listed in Table 1, Nationally Appropriate Mitigation Actions (NAMA) are an emerging concept to promote and facilitate climate change mitigation actions by developing countries.

A wide range of transportation projects in the developing world can secure financing from either crediting mechanisms or institutional funding, by demonstrating the potential to reduce GHG emissions.¹ However, the methods and requirements for demonstrating reductions vary significantly between financing mechanisms and among institutions. Furthermore, financing from different institutions may be given or promised at different points, e.g. GEF financing is intended to provide up-front support for a project, while income from CDM is available after the project is complete and emissions reductions have been verified. Some sources may require only up-front (ex-ante) estimates of expected emissions reductions, while others have requirements for measuring, reporting,

1 – For an overview of climate finance opportunities in the transport sector, see: Binsted, Anne, et al. “Accessing Climate Finance for Sustainable Transport: A Practical Overview.” Sustainable Urban Transport Technical Document #5. GTZ - http://www.transport2012.org/bridging/ressources/files/1/956,TD05_FinGuid.pdf

Table 1. Climate finance sources.

SOURCE	FUNDING ALLOCATED TO DATE	FUNDERS / ADMINISTRATORS	OBJETIVE / FOCUS
MULTILATERAL SOURCES			
Global Environment Facility	US\$8.8 billion (1991 – 2009)	10 MDBs and UN agencies under the UNFCCC	Address global environmental challenges and sustainable development
Clean Technology Fund	US\$4.2 billion (2008 – Jan. 2009)	World Bank and MDBs	Scaled-up financing for demonstration, deployment, and transfer of low carbon technologies
IDB Sustainable Energy and Climate Change Initiative	US\$74.4 million (2007 – 2011)	Inter-American Development Bank	Climate change mitigation and adaptation in LAC
BILATERAL SOURCES			
Fast Start Finance Initiative (Japan)	US\$5.3 billion (2009 – Apr. 2010)	Japanese Ministry of Foreign Affairs	Integrated cooperation, climate change, and development
International Climate Initiative (Germany)	US\$490 million (2008 – 2011)	German Federal Environment Ministry	Climate-friendly economy, adaptation, preservation of carbon sinks
International Climate Fund (United Kingdom)	£ 2.9 billion (2011 – 2015)	United Kingdom Departments for International Development (DFID), Environment and Climate Change (DECC), and Environment, Food and Rural Affairs (DEFRA)	Climate change mitigation and adaptation, reduction of poverty
CARBON MARKETS			
Clean Development Mechanism	US\$72.9 billion (2006 – Sept. 2010)	UNFCCC	Contribute to the objectives of the Kyoto Protocol and sustainable development
Voluntary climate markets	US\$3.4 billion (2009 only)	Various	Sale of emission reductions credits on a voluntary basis

SOURCE: A. BINSTED, D. BONGARDT, H. DALKMANN, AND K. SAKAMOTO (2011). "ACCESSING CLIMATE FINANCE FOR SUSTAINABLE TRANSPORT: A PRACTICAL OVERVIEW." GTZ/BRIDGING THE GAP.

and verification (MRV) – i.e. reporting on actual emission reductions after the project has been implemented (ex-post).

The wide range of financing mechanisms – and their individual methodological requirements – means that in the early stages of planning a project or program, project managers or developers should develop an approach to estimating and monitoring emissions reductions that will meet the requirements of any target funding sources. Whether the manager is working on an individual transport project, a suite of projects, or a comprehensive urban transport, strategy will affect what type of financing mechanisms may be available and will determine what methodologies need to be used. In addition, a project

manager may seek financing for a single project from a suite of projects or an urban transportation plan where the overall program is not eligible for specific funds.

This document seeks to provide guidance for project developers that can apply across this wide array of circumstances. It provides specific guidance for the most common funding sources – CDM, CTF, and GEF – which also have developed specific evaluation and monitoring requirements for transport projects. However, many of the principles and methods discussed in this guidance will be applicable to other existing or proposed climate finance sources as well. The remainder of this section provides an introduction to key sources of carbon and climate finance and their evaluation requirements.

Clean Development Mechanism

Stringent GHG measurement and analysis methods must be used to generate income under the Clean Development Mechanism

The CDM had been the most widespread carbon finance mechanism, with over 5,000 registered projects across multiple sectors. However, while 23% of global energy-related GHG emissions come from the transport sector, only a marginal fraction of the funds expended under the CDM have gone to transport, with around 30 registered projects by the end of 2012. Stringent GHG measurement and analysis methods must be used to access transport-related funding under the CDM, which are required to ensure the environmental integrity of the carbon offsets delivered by CDM projects (i.e. carbon credits issued to a registered CDM project are acquired and used by entities to demonstrate compliance of their GHG emissions limitation targets under a mandatory scheme). Because of its restrictive rules, requirements, and auditing procedures, CDM data collection and analysis is frequently of limited use for broader sustainable transport and urban development planning.

Approved CDM methodologies focused on transport supply include AMS-III.U (cable cars for mass rapid transit), AM0031 (bus rapid transit) and ACM0016 (mass rapid transit). CDM methodologies have also been approved for energy-efficient (AMS-III.AA) and low-emission vehicles (AMS-III.S) as well as the use of biofuels (AMS-III.T and ACM0017). CDM Programs of Activities (PoA) have also been proposed as a way to reduce high CDM transaction costs, including also costs in the transport sector.² GHG evaluation requirements for CDM methodologies for transport supply/demand projects are described in detail in Part IV of this document.

2 – Dalkmann, Holger. (2009). Post 2012 - scenarios for future MRV requirements for the transport sector, STAP-ADB Workshop, Asian Development Bank, Manila, Accessed at: <http://www.adb.org/Documents/Events/2009/Scientific-Technical-Advisory-Panel/GEF-STAP-Manila-Dalkmann.pdf>.

Clean Technology Fund

Stringent criteria of CTF for evaluation of cost-effectiveness and additionality demonstration in comparison with alternatives, among others, are also posing a barrier to initiating CTF sustainable transport projects

The CTF is one of the Climate Investment Funds (CIF) created in 2008 as an interim source by the World Bank in cooperation with the multilateral development banks (MDBs) to bridge the gap between current and future climate regime under the UNFCCC. It is designed to leverage and complement other private, bilateral, and multilateral sources. The CTF can provide grants, loans, and project risk mitigation instruments.³

CTF uses several criteria to assess and prioritize proposed programs and projects, including potential GHG emissions reductions, cost-effectiveness, replication potential, and development impact. CTF may fund many different types of activities, including, "...transportation investments resulting in significant emissions reductions (CO₂ per passenger-kilometer or per ton-kilometer) through modal shifts, fuel efficiency or alternative fuel options: (i) Modal shift to low carbon public transportation in major metropolitan areas, with a substantial change in the number of passenger trips by public transport; (ii) Modal shift to low-carbon freight transport, with a substantial change in tonnage of freight moved by road transport to rail; (iii) Improve fuel economy standards and fuel switching; (iv) Deployment of electric and hybrid (including plug-in) vehicles..."⁴

It is important to note that, "CTF could fund technologies that CDM is failing to deploy at scale or where CDM is unable to provide support – such as financing...transport

energy efficiency."⁵ As of mid-2011, 13 CTF investment plans for a dozen countries amounting to US\$4.4 billion in co-financing had been approved, and 21 projects totaling US\$1.5 billion in CTF co-financing had been approved. Of these, transport sector projects in LAC have been approved in Mexico and Colombia.

GHG appraisal is a core part of developing projects for CTF funding. The guidance for the CTF monitoring and evaluation anticipates that five to eight years will be required to produce the outputs and outcomes of the program, with another one to five years to spur replication. The guidance suggests a focus on MDB project output and outcome monitoring over this time frame and notes that, "the resources for, and management of, these evaluations need to be considered early on in the process to ensure that they are planned and take place," and that, "setting up a results monitoring system takes time and requires resources."⁶

The requirements of CTF for evaluation of performance and cost-effectiveness, among others, are posing a barrier to getting CTF projects off the ground, as these requirements entail considerable data collection, tool development, and modeling. Clearly, however, it would be prudent in establishing monitoring and evaluation systems for any CTF initiatives, to focus also on broader institutional capacity building for sustainable transport system data collection, monitoring, and program evaluation.

3 – Binsted et al. (2011). Op. cit.

4 – Climate Investment Funds (2009). Clean Technology Fund Investment Criteria for Public Sector Operations, http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/CTF_Investment_Criteria_Public_sECTOR_revisedFeb9.pdf

5 – Climate Investment Funds (2009). Clean Technology Fund Investment Criteria for Public Sector Operations. Op.cit.

6 – Climate Investment Funds (2010). Clean Technology Fund Results Framework, <http://www.climateinvestmentfunds.org/cif/sites/climateinvestmentfunds.org/files/CTF%20%20Results%20Framework%20Nov2010.pdf>



Global Environment Facility

Relatively simpler analysis tools can be used to develop ex-ante estimates of GHG impacts of transport investments as part of program and project preparation in relation to the Global Environment Facility

The GEF is the financial mechanism established under the UNFCCC and other multilateral environmental agreements to address global environmental issues. The GEF provides grants to developing countries and countries with economies in transition for projects related to climate change as well as other global environmental issues such as biodiversity and land degradation. Since 1991, the GEF has allocated US\$10 billion, supplemented by more than US\$47 billion in co-financing, to more than 2,800 projects in more than 168 countries. The GEF partnership consists of 10 agencies, including the IDB as well as other international development banks and UN agencies.⁷

The GEF has supported transport interventions since 1999 and focuses on interventions in land transport, mostly in urban areas, approving US\$249 million for 45 projects between 1999 and June 2010. Relatively simpler analysis tools can be used to develop ex-ante estimates of GHG impacts of transport investments.

The GEF can fund a much broader range of transport project types compared to CDM, for which only a few methodologies have been approved. GEF may also to some extent be broader in its range than CTF, which has a primary focus on technology, although CTF is now recognized to include technology to encourage mode shift, such as rapid transit.

Historically, projects have used a wide range of methodologies to calculate or estimate ex-ante GHG emission reductions, since no dedicated assessment methodology had been established. In 2009, however, the GEF Scientific and Technical Advisory Panel (STAP) initiated the development of a dedicated GHG assessment methodology for transport projects. This was recently published as the Manual for Calculating Greenhouse Gas Benefits of Global Environment Facility Transportation Projects.⁸ The requirements for GEF project evaluation are described in more detail in Part IV of this document.

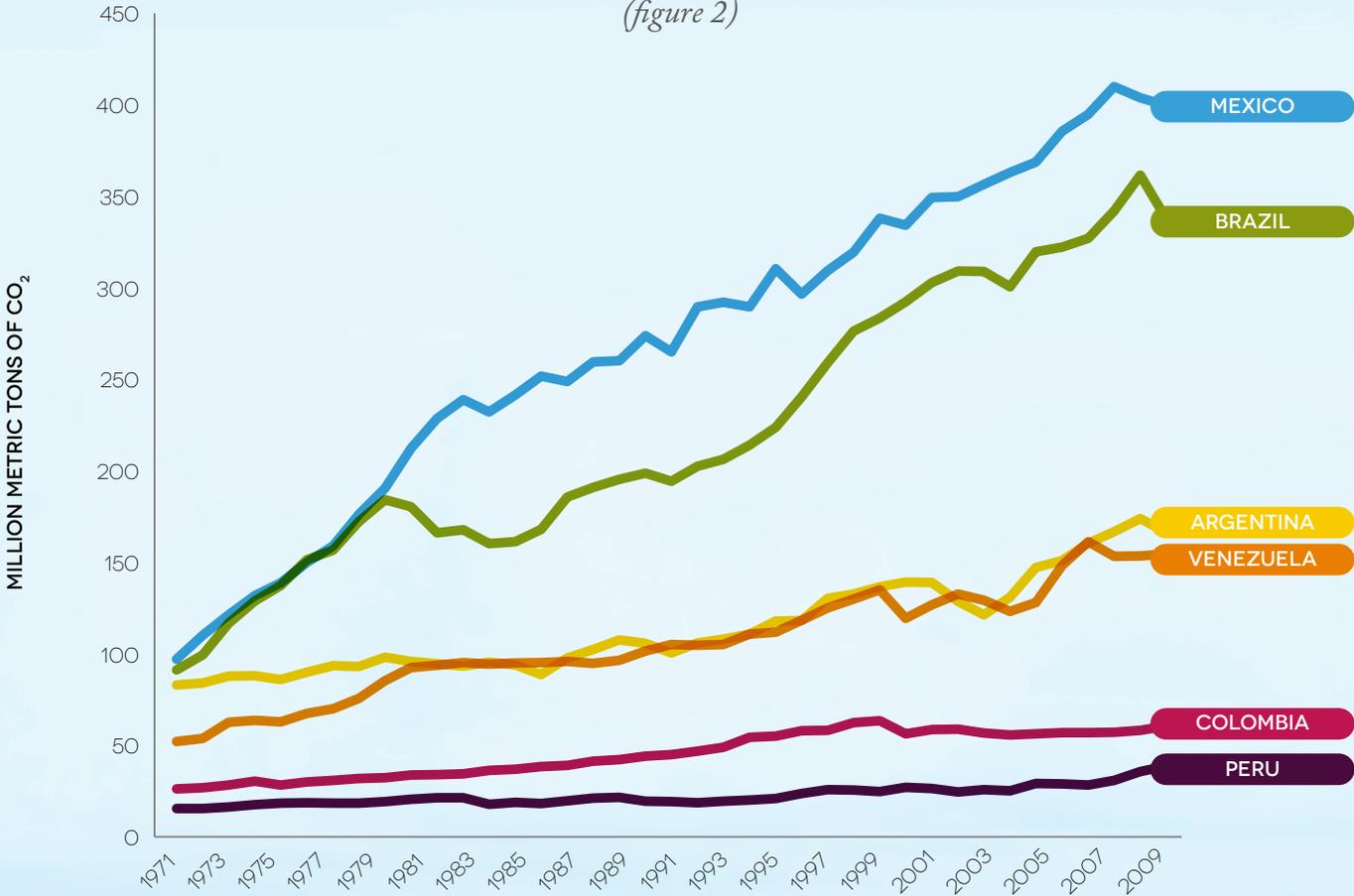
7 – <http://www.thegef.org/gef/>

8 – Scientific and Technical Advisory Panel of the Global Environmental Facility. Manual for Calculating Greenhouse Gas Benefits of Global Environment Facility Transportation Projects. October 2011, <http://www.unep.org/stap/calculatingghgbenefits>

Transportation and Climate Change: Opportunities for Latin America

ENERGY-RELATED CARBON DIOXIDE EMISSIONS
IN SELECTED LATIN AMERICAN COUNTRIES

(figure 2)



SOURCE: INTERNATIONAL ENERGY AGENCY 2011

Climate change is occurring at a rapid pace due to increases in anthropogenic (human-induced) GHG emissions that affect the earth's temperature. While all regions will face serious consequences of climate change, LAC is likely to be particularly affected by predicted extreme weather events, flooding, drought, water scarcity, public health crises, reduction in crop yields (and increase in food insecurity), and species extinction.⁹ Countries in the region are already experiencing some of these impacts. The UNFCCC stresses the need to reduce anthropogenic GHG emissions to prevent the worst effects of climate change. As Figure 2 shows, many Latin American countries' GHG emissions have increased significantly in recent years.

Transportation contributes a substantial portion of anthropogenic GHG emissions and therefore has a significant role to play in reducing emissions. Transportation, including road, air, water and other modes, represented 15% of global GHG emissions and 23% of GHG emissions from fossil fuel combustion in 2009 as shown below.¹⁰ However, the contribution from the transport sector could be as high as 21% of global GHG emissions when the full life-cycle or "well-to-wheel-to-disposal" GHG impacts of a motor vehicle are included. The full life-cycle includes GHG emissions related to fuel production and distribution, and to the manufacturing, maintenance, and scrappage of motor vehicles.¹² Including the production and maintenance of transportation infrastructure, with its embedded material content, it would further increase its share. Most existing methodologies do not account for the full life-cycle GHG impacts of transportation projects and programs, although some have been developed to specifically examine construction impacts of infrastructure, and some may add "full fuel-cycle" emissions to account for fuel production and distribution, in addition to combustion.

In LAC, there is a trend of increasing motorization – more people owning personal vehicles and/or driving personal vehicles more.¹¹ This is partially a function of increasing incomes. This trend is suggested in Figure 5, which illustrates a model showing how vehicle ownership typically increases with higher per capita income until income approaches about US\$30,000. However, there is evidence that the tendency towards increased motor vehicle ownership and use can be altered by such factors as better public transportation, increased urbanization and urban density, patterns of urban design favoring walking and cycling, and more modest investment in roads.¹² Several Latin American cities, such as Sao Paulo and Bogota, have reduced the rate of motorization and motor vehicle use through public and non-motorized transit strategies. As Figure 6 shows, South Korea has one-third lower vehicle ownership than the U.S. at comparable income levels, the product of South Korea's high density urban development, heavy public transport investment, and public policies to manage private motor vehicle use.

The transportation sector presents important opportunities to mitigate climate change while promoting economically efficient and effective social development. Projects to reduce GHG emissions in the transportation sector – especially mass transit, non-motorized transit, or land use initiatives – can not only reduce GHG emissions compared to business as usual (BAU) trends of rapid motorization and sprawl development, but can also improve public health, reduce social inequality, and improve economic competitiveness of cities.¹³ As Figure 7 shows, there is a significant relationship between urban density and transport-related energy consumption, but cities with comparable overall density, such as Mexico City and Bogota, can achieve quite different energy consumption, depending on many factors, such as transport investment and management policies.

9 – United Nations Framework Convention on Climate Change. (2007)

10 – This estimate is based on the previously cited OECD/ITF data (15 percent of global emissions), combined with estimates from the U.S. that well-to-tank emissions for light-duty vehicles represent about 20 percent; tank-to-wheels 70 percent, and "cradle to grave" vehicle materials 10 percent of total life-cycle GHG emissions for a vehicle.¹¹ See: DeCicco, J.M. (2010)

11 – P. Christopher Zegras and Ralph Gakenheimer. (2006)

12 – J. Dargay, D. Gately & M. Sommer. (2007)

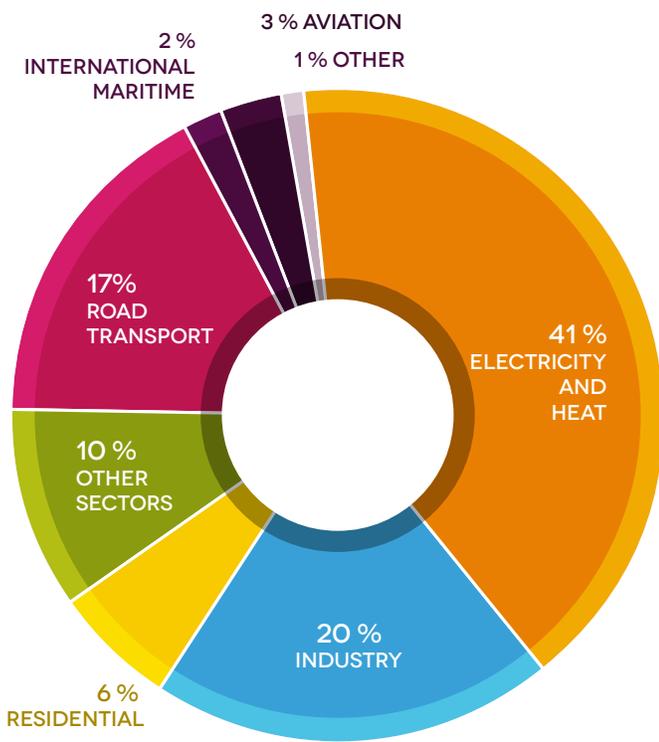
13 – Winkelmann, S., Bishins, A., & Kooshian, C. (2010)

Freight contributes a growing share of GHG from transport, especially in LAC, as Table 2 below shows. About half of carbon dioxide emissions from transport in Latin America are from freight, mostly from medium and heavy-duty trucks. Together, these exceed the carbon dioxide emissions of light duty passenger vehicles in

Latin America. Many cost-effective alternatives to reduce GHG emissions from the transport sector concern freight logistics and the shifting of freight to lower carbon modes of transport. Many of these strategies also produce large public health benefits due to reductions in air pollution, accidents, noise, and other negative externalities.

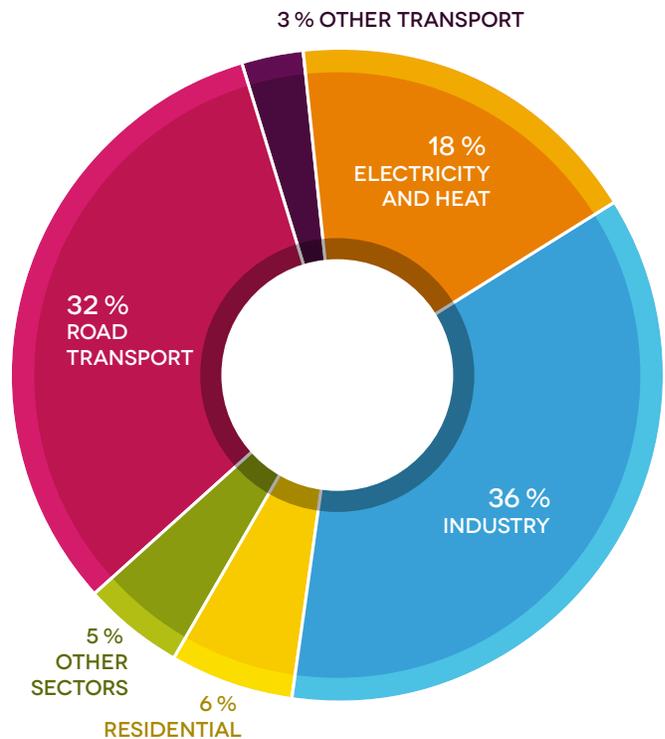
GLOBAL CARBON DIOXIDE EMISSIONS FROM FUEL COMBUSTION (2009)

(figure 3)



LATIN AMERICA CARBON DIOXIDE EMISSIONS FROM FUEL COMBUSTION (2009)

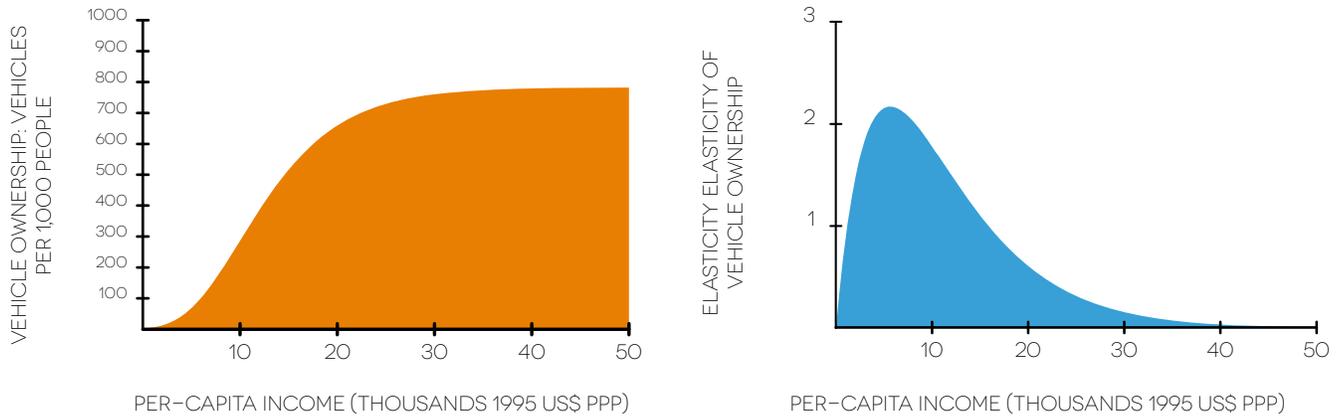
(figure 4)



SOURCE: INTERNATIONAL ENERGY AGENCY 2011

GOMPERTZ FUNCTION AND IMPLIED INCOME ELASTICITY FOR VEHICLE OWNERSHIP

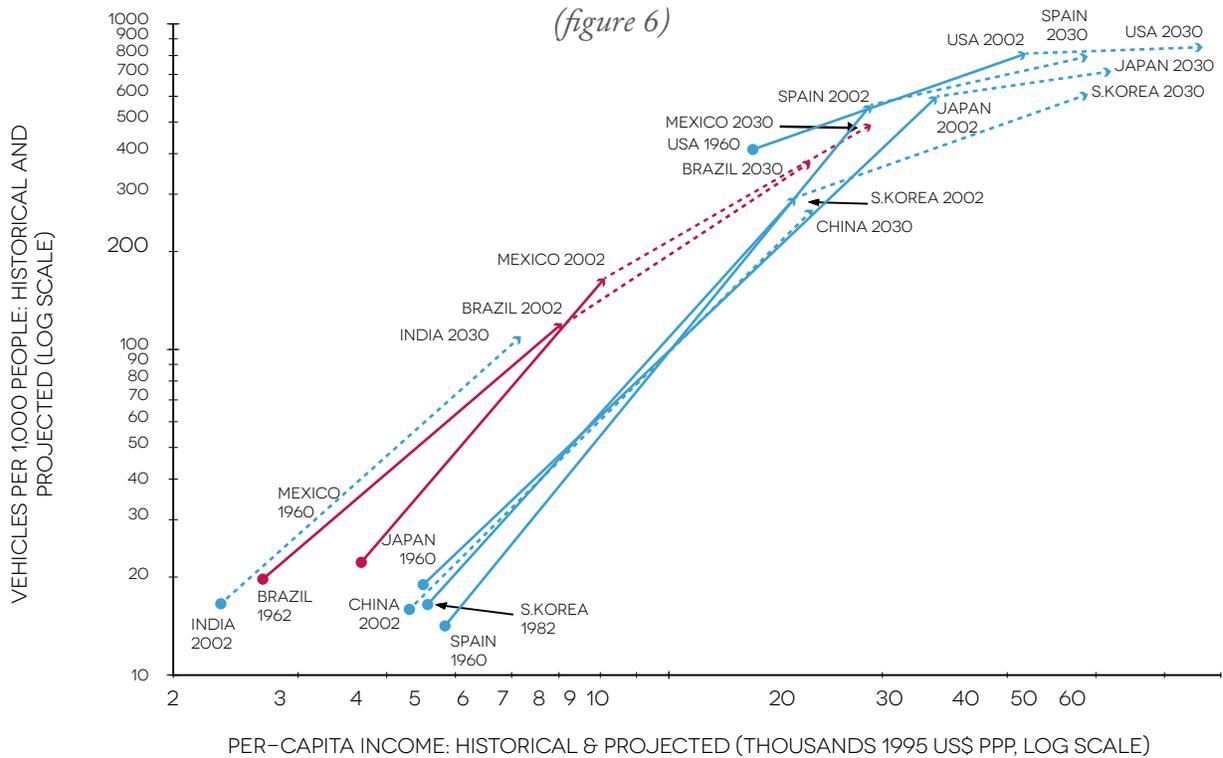
(figure 5)



SOURCE: DARGAY, J. GATELY, D. AND SOMMER, M. 2007

HISTORICAL AND PROJECTED INCREASES IN MOTOR VEHICLE OWNERSHIP BY COUNTRY

(figure 6)



SOURCE: DARGAY, J. GATELY, D. AND SOMMER, M. 2007



URBAN DENSITY AND TRANSPORT-RELATED ENERGY CONSUMPTION

(figure 7)

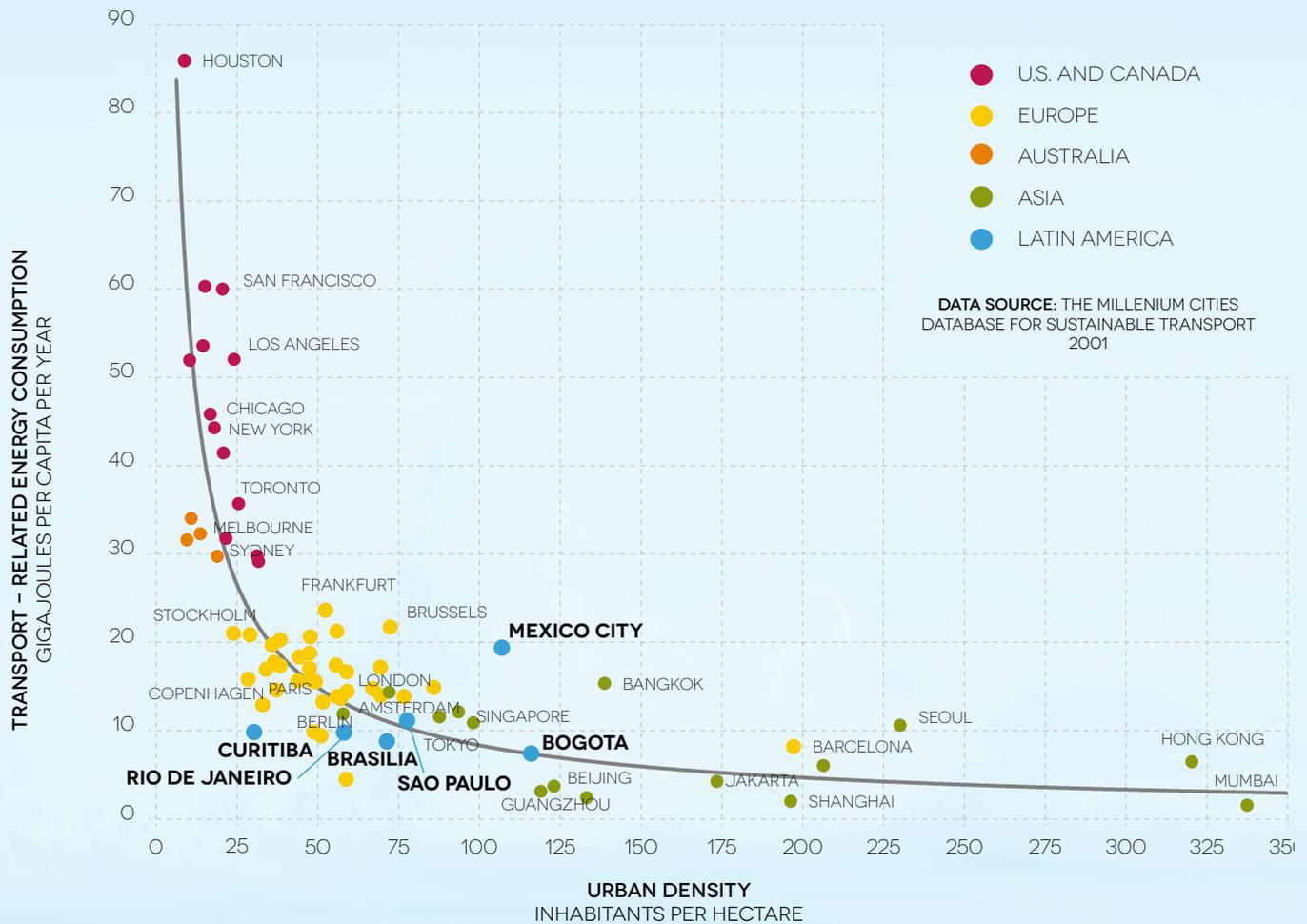


Table 2. Latin America motor vehicle carbon dioxide emissions by vehicle type 2000¹⁴

VEHICLE TYPE	VEHICLES (100,000)	KM / YEAR	ENERGY, EJ	EMISSIONS MTONNES CO ₂	SHARE OF TOTAL CO ₂ EMISSIONS
LDV Pass	40,127	13,000	2.1	155.4	40.70 %
Motorcycles	6,978	7,500	0.05	3	0.80 %
Minibuses	930	40,000	0.21	14.1	3.80 %
Buses	511	40,000	0.2	14.5	3.90 %
LDV Freight	4,459	13,000	0.23	16.2	4.40 %
Med Trucks	5,385	22,000	1.15	77.6	20.80 %
Heavy Trucks	2,314	50,000	1.38	92.2	24.70 %
Total	—	—	5.33	372.9	—

NOTE: 1 EJ (exajoule = 10¹⁸ joules) = 24 MTOE (Million Tonnes of Oil). Data adjusted to include Mexico.

14 – Shipper, Lee et al. (2009).

Part 2

Overview

of Transportation GHG Mitigation Strategies

How Transportation Strategies Affect GHG Emissions

For much of the 20th Century, many transport engineers world-wide approached traffic problems with the belief that congestion and other environmental issues could be solved by predicting future traffic growth in an area and building new road capacity to serve that forecasted demand. This belief was built on the correct understanding that stop-and-go traffic, low travel speeds, and rough, poorly-maintained roads are typically associated with greater traffic delay and higher levels of fuel use (and related GHG emissions) per unit of distance traveled by any given motor vehicle. This is illustrated in Figure 8, which shows how keeping speeds within a moderate speed range (35 to 65 mi/h, or about 60 to 100 km/h) and smoothing traffic flow for a given average speed both reduce CO₂ emissions. While Figure 8 is based on U.S. data, Figure 9 provides illustrative relationships between speed and emissions for vehicles in developing countries, taken from the Transport Emissions Evaluation Model for Projects (TEEMP) tool developed for GEF and the Asian Development Bank.

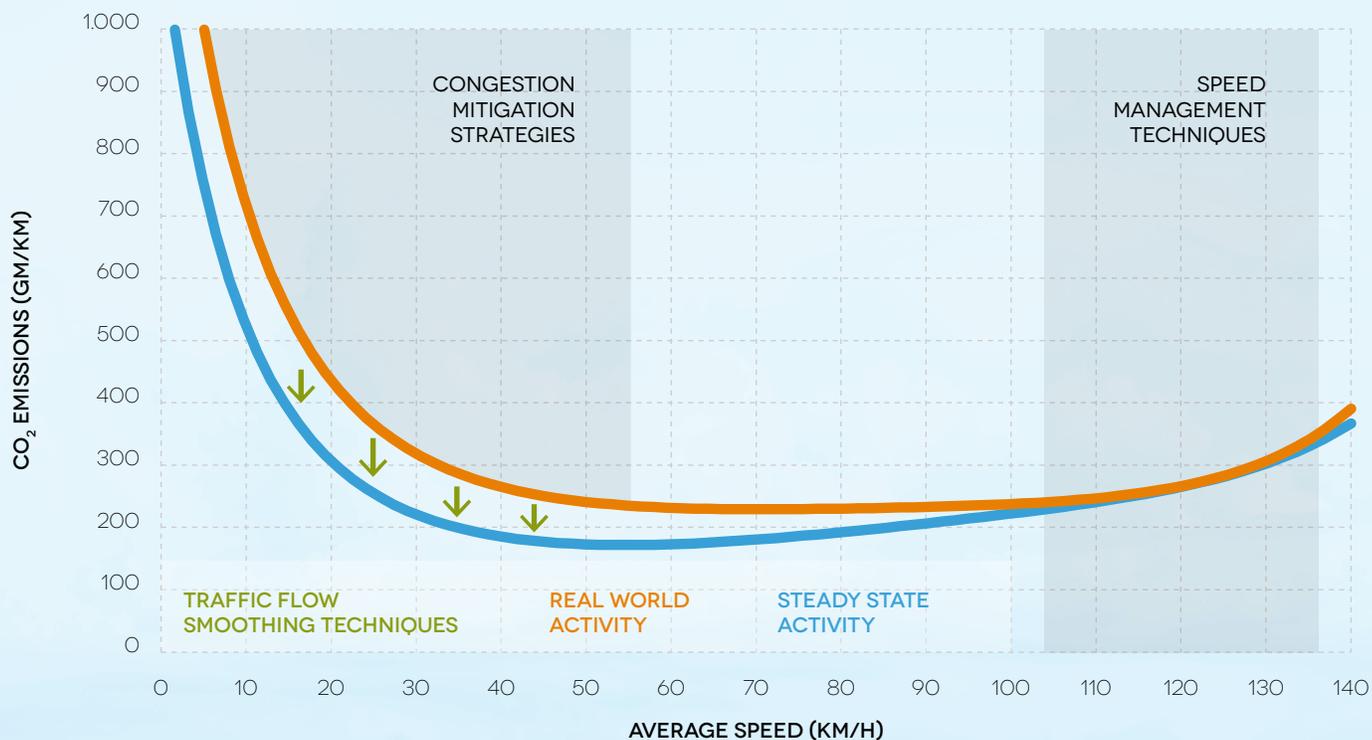
What this “predict-and-provide” paradigm failed to account for, however, is induced traffic. In countless areas across the world, efforts to build our way out of traffic congestion with supply-side solutions have failed to curb congestion and have spurred more, not less motor vehicle traffic congestion and pollution. In the context of growing metropolitan areas, new highway capacity often induces so much new traffic that within a few years the wider,

bigger, or faster roads have been filled with new traffic and the congested speed of travel reverts back to what it was before the road expansion. Building new highways and expanding old ones with flyovers or additional lanes can boost mobility and are appropriate in some circumstances. However, if implemented in isolation, these actions often exacerbate, rather than solve long-term congestion and environmental pollution problems. Building and improving roads in rural areas often has less of an induced traffic effect than expanding urban highways. But in general, it is widely acknowledged that investment in any particular mode of transport – whether roads, railways, waterways, bus transport, walking, or cycling – will tend to encourage greater use of that mode of transport over time relative to other modes. How street space is allocated, managed, and priced tells people how to travel and shapes how goods reach markets.

In place of the discredited “predict-and-provide” paradigm of old-school traffic engineering, a new, more holistic approach has emerged and won widespread acceptance as a foundation for sustainable mobility planning and system development. This is frequently characterized as the “Avoid-Shift-Improve” (ASI) paradigm, as illustrated in Figure 10. This approach aims to meet key performance goals for the transport system by balancing both supply and demand focused transport measures and investments to:

RELATIONSHIP BETWEEN LIGHT-DUTY VEHICLE AVERAGE SPEEDS AND CARBON DIOXIDE EMISSIONS

(figure 8)



SOURCE: BARTH & BORIBOONSOMSIN 2008, BASED ON U.S. VEHICLE TEST

- » **Avoid unnecessary travel** activity through more effective spatial, logistical, and communications systems;
- » **Shift travel from less efficient to more efficient modes** (e.g. from car or minibus to high efficiency public transport, or from truck to rail, or from partially loaded unibody trucks to fully loaded tractor-trailers); or,
- » **Improve the efficiency of the remaining travel activity** through either improved vehicle design or more effective management of transport system operations and networks.¹⁵

Key performance measures for sustainable transport systems typically are defined as including:

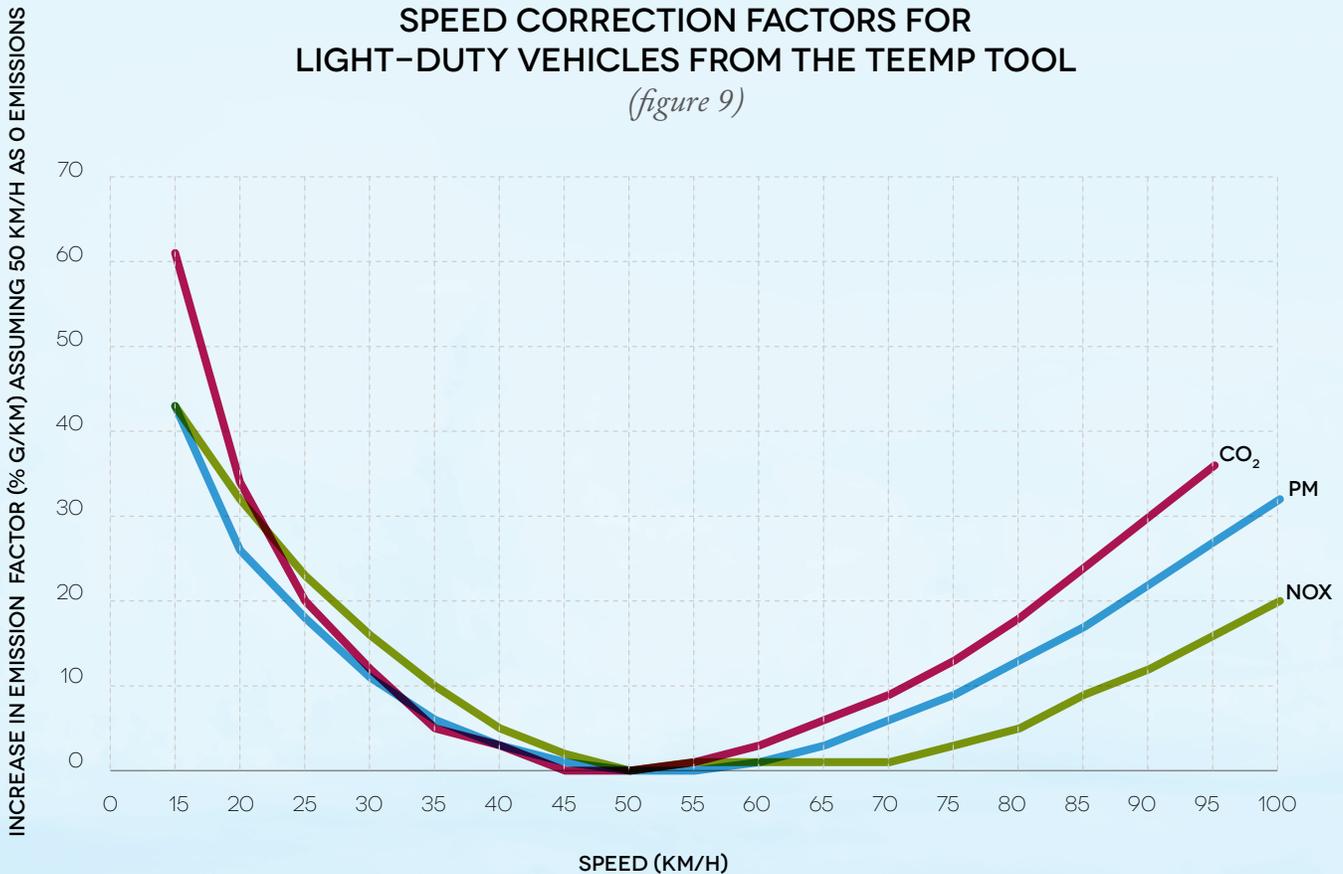
- » Improving access to connect people to opportunities and resources and goods to markets;
- » Supporting more equitable economic development by reducing transport costs in ways that enable more effective resource utilization and equitable access for the transport disadvantaged;
- » Reducing adverse environmental impacts including air and water pollution, degradation of terrestrial and aquatic ecosystems and aquifers, and GHG emissions;

15 – Dalkman, H. & Brannigan, C. (2007)



SPEED CORRECTION FACTORS FOR LIGHT-DUTY VEHICLES FROM THE TEMPT TOOL

(figure 9)



SOURCE: GEF MANUAL FOR CALCULATING GHG BENEFITS OF TRANSPORT PROJECTS

Box 1: What is “induced traffic”?

Induced traffic (or more generally, “induced demand” or the “rebound effect”) is an increase in travel that results from improved travel conditions. Roadway capacity expansion, or other improvements that reduce congestion or travel times (such as more efficient operations), have been found over time to lead to increases in traffic, as more people take advantage of the improved facility. Induced travel can also occur with transit or non-motorized modes, as faster, cheaper, or more convenient options encourage people to travel more.

Induced traffic reflects a benefit of greater mobility. However, with motorized modes it works counter to GHG reduction objectives. In the long run, the added GHG emissions from the induced traffic may exceed the savings produced by the initial congestion reduction, especially as roads fill to their new capacity and congestion returns to former levels.

THE ASI APPROACH TO SUPPORTING SUSTAINABLE, LOW CARBON TRANSPORT

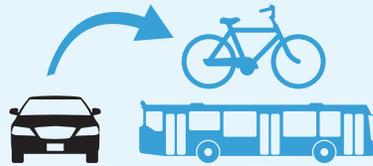
(figure 10)



AVOID

Motorized trips

- Motor and fuel taxes
- Road user fees / tolls
- Cordon / congestion pricing
- Car sharing programs
- Transit Oriented Development
- Car free zones
- Commuter trip reduction policies
- Avoid freight empty loads
- Better freight logistics



SHIFT

To more efficient modes of transportation

- Public transport improvements
- Parking management
- Transit Oriented Development
- Improvement in NMT
- Freight rail



IMPROVE

Efficiency of remaining travel activity

- Active traffic management
- Eco-driving
- Fleet maintenance schemes
- Intelligent transportation systems
- Traffic signal synchronization
- Energy efficient vehicles
- Lower carbon fuels
- Aerodynamic vehicle design

- » Improving public health and safety by reducing traffic accidents and exposure to unhealthful pollutants, and by increasing use of healthful, physically active transportation modes.

This report describes methodologies for quantifying the GHG impacts of avoid-shift-improve strategies, focusing particularly on strategies that are likely candidates for inclusion in sustainable mobility plans in metropolitan areas. Some of these same methodologies readily support evaluation of impacts on air pollution and other aspects of transport system performance.

It is most often advantageous to undertake broad-based performance evaluations to consider the multiple local and global benefits of sustainable transport strategies rather than focusing narrowly on GHG impacts, as most

transport decisions are undertaken not for their climate benefits but to meet more immediate local objectives, such as improving safety, economic development, community livability, and public health. Most sustainable transport strategies discussed in this report contribute to these multiple objectives.

GHG abatement cost curve methodologies, as pioneered by analysts like McKinsey & Company, have found it difficult to incorporate these other benefits into reductionist appraisals of cost-effectiveness of GHG mitigation strategies. As a result, low-carbon transport strategies have often been overly focused on technology fixes and have missed harder-to-quantify strategies that involve improved transport system management, operations, pricing, and policy or low-carbon integrated land use and transport planning.



Overview of Avoid-Shift-Improve Strategies

This section provides a brief overview of key strategies to mitigate transport GHG emissions through avoiding travel, shifting to more sustainable modes, and improving the efficiency of travel. Forty strategies are discussed under the following eleven broad categories:

- 1. Public transportation improvements.**
Attractive, safe, and reliable public transport is an essential foundation for the growth and sustenance of low-carbon urbanization.
- 2. Non-motorized transportation.**
Attention to street space allocation, management, and design is vital to retaining walking and biking trips and also ensuring these modes are safe and attractive for all. Walking is essential to making public transport attractive. Both public transport and NMT are also known as “pull” strategies, because they can be used to pull users toward these types of transport.
- 3. Pricing and subsidies.**
Appropriate pricing, including removal of subsidies, can help manage automobile use by helping drivers recognize the costs associated with the use of private vehicles. How much, when, and how travelers pay for mobility can have a profound effect on travel behavior. These strategies are often called “push” strategies because they can be used to push drivers out of the car into cleaner more efficient modes of transport.
- 4. Land use.**
The arrangement of jobs, housing, commercial, and public space does a lot to determine how much people need to travel and shapes whether it is more convenient to walk, cycle, use public transport, or drive using private motor vehicles.
- 5. Parking management.**
Parking is perhaps the most important link between land use and transportation. Excess parking makes walking difficult and encourages driving. Less parking and appropriately priced and located parking can cut automobile travel and traffic congestion.
- 6. Commuter trip reduction.**
How employers manage the circumstances and incentives for employee commuter travel and working arrangements can have a dramatic effect on traffic and automobile use, as well as the quality of work life and the attractiveness of the workplace.

7. **Motor vehicle access and use.**

Other policies and programs directed at vehicle ownership and use can encourage reduced use of motor vehicles for personal travel, either by restricting motor vehicle ownership and use, or by providing attractive alternatives to car ownership through car-sharing.

8. **System operations and management.**

These strategies include an array of approaches to cut emissions through more fuel-efficient driving, more efficient traffic operations, and improved vehicle maintenance.

9. **Roadway capacity.**

Roadway capacity expansion, including removal of bottlenecks or other additions to capacity, may provide short-term benefits through improved traffic flow. However, in the long-run, GHG savings are often offset by “induced demand” created as a result of improved vehicular mobility. Therefore, roadway capacity expansion should be carefully evaluated if it is intended as a GHG reduction strategy. In some cases, GHG mitigation objectives may even be better served by eliminating highway structures that impede non-motorized or transit access.

10. **Multimodal freight.**

A variety of freight-oriented strategies can be applied to shift a portion of freight from less efficient trucks into potentially more efficient and cleaner rail and marine modes; optimizing freight loads by reducing empty back-hauls and increasing the capacity utilization of freight vehicles; and boosting the fuel efficiency of truck shipments.

11. **Vehicle energy efficiency and fuel switching.**

The fuel efficiency of vehicles can be significantly improved and GHG emissions reduced through a number of already existing technologies. For road vehicles, these technologies include reduction of aerodynamic drag and rolling resistance, efficient engines including turbocharging (with smaller engines), fuel-electric hybrids (with regenerative braking), improved transmission, idle-stop, etc. for rail, they include regenerative braking and other measures. For shipping, they include reduced hydrodynamic resistance through improved hull coatings, etc. There are also mitigation opportunities through switching to fuels with lower carbon content. Plug-in hybrids and all-electric vehicles reduce emissions where the grid emissions factor is low (e.g. with a significant share of renewable sources). Finally, biofuels may also reduce emissions, depending on the life-cycle emissions of biofuel production, including land-use changes.

Table 3 summarizes the effects that each of these categories of strategies has on avoiding trips, shifting trips to more efficient modes, or improving the efficiency of travel.

Table 4 offers some first order generalizations about the likely difficulty and cost of implementing each strategy in LAC and the likely effectiveness of each strategy to reduce vehicle kilometers of travel (VKT) and GHG emissions. While the assessments shown in the table are qualitative, a general rating scale for each factor is provided below for consistency. In many cases, both effectiveness and implementation difficulty will also vary depending upon how aggressively the policy is implemented (e.g. amount of a motor fuel tax or vehicle registration fee).



Implementation difficulty is rated as follows:

- » **Low:** Few political and institutional barriers, relatively easy to overcome.
- » **Medium:** Some political and institutional barriers, but have been overcome in practice.
- » **High:** Strong political opposition, widespread lack of public acceptance, and/or major institutional coordination required. Very few examples of successful implementation.

Implementation costs are rated as follows:

- » **Low:** Involves only modest construction (e.g. traffic calming, bike lanes), operations strategies (e.g. changing signal timing), or strategies that primarily incur administrative/programmatic and enforcement costs (e.g. pricing, transportation demand management, parking management, land use policies). Typically requires investments of less than US\$1 million per kilometer or per location covered, and in the low millions of dollars for area-wide applications.
- » **Medium:** Involves moderate infrastructure improvements (e.g. public transport improvements featuring some BRT system components, such as pre-board fare collection and platform-level boarding, lane additions at intersections, and cycle track network) or area-wide programs such as congestion pricing. The investments are in the range of US\$1 to 10 million per kilometer or per location covered, and in the tens of millions of dollars for area-wide applications.

- » **High:** Requires major construction projects (incl. roadways, gold standard BRT systems, mass rapid transit (MRT) systems, railways, etc.), other major infrastructure (e.g. area-wide intelligent transportation systems (ITS)), or costly services (e.g. transit operations). Investments necessary are in the range of the tens of millions of dollars per kilometer or per location covered, and in the hundreds of millions of dollars for area-wide applications.

VKT and GHG reduction impacts are rated as follows:

- » **Low:** Strategy typically has less than 2% impact at the scale of application (i.e. site, corridor, or regional).
- » **Medium:** Strategy typically can provide in the range of a 2-10% impact at the scale of application.
- » **High:** Strategy typically can provide at least a 10% impact at the scale of application.

Table 3. Transport GHG reduction strategies: Effects according to ASI

TRANSPORT GHG REDUCTION STRATEGY	AVOID	SHIFT	IMPROVE
Public transportation improvements		Makes public transport more attractive relative to private car use	Promotes more energy-efficient vehicles and operations and less carbon-intensive fuels
NMT		Makes NMT more attractive relative to private car use	
Pricing and subsidies	Discourages low-value, high-social-cost trips	Makes auto use less attractive relative to other modes	Reduces peak-period congestion
Land use	Reduces need for long trips by locating origins and destinations in close proximity	Makes transit and NMT more viable for more trips	
Parking management	Discourages low-value, high-social-cost trips	Encourages alternatives to driving and improves pedestrian environments	Reduces parking search time
Commuter trip reduction	Provides work-at-home/reduced work day options	Promotes incentives to non-auto commuting	Reduces peak-hour congestion
Motor vehicle access and use	Discourages vehicle ownership and use	Makes zero-car households more likely and discourage vehicle ownership and use	Reduces congestion
System operations and management		Provides better information on transit alternatives	Reduces congestion and keeps vehicles operating at more efficient speeds
Roadway capacity			Reduces congestion
Multimodal freight	Reduces low-productivity freight trips	Makes more efficient modes more attractive and discourages the use of less efficient modes	Introduces cleaner, more efficient vehicles, and fuels with a lower carbon content
Vehicle energy efficiency and fuel switching			Introduces cleaner, more efficient vehicles, and fuels with a lower carbon content

Table 4. Transport GHG reduction strategies: Implementation challenges and impacts

TRANSPORT GHG REDUCTION STRATEGY	IMPLEMENTATION DIFFICULTY	IMPLEMENTATION COSTS	VKT REDUCTION	GHG EMISSIONS REDUCTIONS
PUBLIC TRANSPORTATION IMPROVEMENTS				
Operational improvements	Medium	Low	Medium – High	Medium – High
Fare system improvements	Medium	Low	Low - Medium	Low – Medium
System integration in priority corridors	Medium – High	Low – Medium	Medium	Medium
Bus rapid transit	Medium	Medium – High	Medium – High	Medium – High
Light rail, metro rail, and commuter rail systems	High	High	Medium – High	Medium – High
Bus useful life regulation and vehicle phase-out, scrappage programs	Low – Medium	Low – Medium	Medium	Medium
NON-MOTORIZED TRANSPORTATION ^a				
New and improved sidewalks and pedestrian crossings	Low	Low – Medium	Low – Medium	Low – Medium
Traffic calming	Low	Low	Low – Medium	Low – Medium
Improved bicycle infrastructure, networks, and support programs	Low	Low – Medium	Medium	Medium
PRICING AND SUBSIDIES				
Motor fuel taxes and subsidies	Medium	Low	High	High
Road user fees and tolls for new(N)/existing(E) roads	Low(N) – High(E)	Medium	Low(N) – Medium(E)	Low(N) – Medium(E)
Congestion pricing new(N)/existing(E) roads	Medium(N) – High(E)	Medium	Low(N) – Medium(E)	Low(N) – Medium(E)
Cordon pricing	High	Medium	High	High
LAND USE ^b				
Urban planning codes and practices	Medium	Low	Medium – High	Medium – High
Transit oriented development (TOD)	Medium	Low	Medium – High	Medium – High
Car free zones & restricted traffic streets	Low	Low	Medium	Medium
PARKING MANAGEMENT ^c				
Parking pricing	Medium	Low	Medium	Medium – High
Managing on-street parking supply	Medium	Low	Low – Medium	Low – Medium
Parking requirements	Low – Medium	Low	Low – High	Low – High
COMMUTER TRAVEL REDUCTION				
Flextime schedules	Low	Low	Low	Low
Compressed work weeks and telework	Low – Medium	Low – Medium	Low – Medium	Low – Medium

TRANSPORT GHG REDUCTION STRATEGY	IMPLEMENTATION DIFFICULTY	IMPLEMENTATION COSTS	VKT REDUCTION	GHG EMISSIONS REDUCTIONS
Rideshare matching and incentives	Low	Low	Medium	Medium
Tax incentives for alternative mode use and disincentives for employer provided free parking	Medium	Low – Medium	Medium	Medium
MOTOR VEHICLE ACCESS AND USE				
Car-sharing programs	Low	Low - Medium	Low	Low
Motor vehicle registration fees and taxes	Low – Medium	Low	Low – Medium	Low – Medium
Motor vehicle quota systems	High	Low	High	High
License plate restrictions	Medium – High	Low	Medium	Medium
SYSTEM OPERATIONS AND MANAGEMENT				
Reduce national speed limits on motorways	Medium	Low	Low	Medium
Eco-driving and vehicle maintenance	Low	Low	Low	Low - Medium
Intelligent transportation systems ^d	Medium – High	Medium - High	Low	Low – Medium
ROAD CAPACITY				
Roadway capacity expansion	Medium	High	Negative	Low – Medium (SR); Negative (LR) ^e
MULTIMODAL FREIGHT ^f				
Enhancement of intermodal freight infrastructure	Medium – High	High	Medium	Medium
Freight pricing and management	Medium	Low	Low – Medium	Medium
Regional freight distribution centers, inland ports, and logistics parks	High	Medium	Low – Medium	Low – Medium
VEHICLE ENERGY EFFICIENCY AND FUEL SWITCHING				
Efficient cars and motorcycles	Medium	Low – Medium	Low	Medium - High
Efficient trucks	Medium	Low – Medium	Low	High
Biofuels	Low	Low	Low – Medium ^g	Low – Medium ^g
Electric road vehicles	Medium – High	High	High	Low – High ^h
Efficient ships	Low – Medium	Low	Medium	Medium

^a The “medium” effectiveness ratings for non-motorized strategies reflect a comprehensive program of city-wide improvements. Isolated improvements may provide “low” effectiveness.

^b Effects of land use strategies depend upon timeframe – medium for mid-term, high for long-term.

^c Effects of parking management may be “high” if implemented comprehensively on a citywide basis, but low to medium if implemented on an isolated basis.

^d Ratings for ITS are based on a comprehensive system of ITS strategies.

^e SR = short run (<5-10 years); LR = long run (>5-10 years).

^f Very limited information available on the effectiveness and costs of many freight strategies.

^g Effect depend on emissions associated with biofuel production, especially land use changes.

^h Effect depend on emission factor of electricity grid.



Effects of Strategies on GHG Emissions

Public transportation improvements

Good public transportation is a vital foundation for modern cities to grow in size and achieve higher density, better standards of living, mixed land-use, and reduce its carbon footprint. Comprehensive sustainable mobility plans should consider all of the following options for improved transit service:

- » Operational improvements;
- » Fare system improvements;
- » Service integration in priority corridors;
- » Implementation of integrated BRT corridors;
- » MRT, including new systems or expanded service on existing systems; and
- » Fleet modernization through useful life regulation, incentives to the adoption of more efficient, cleaner vehicles, and phasing-out of obsolete vehicles.

Public transport improvements can reduce GHG emissions through both “Shift” and “Improve” mechanisms. “Shift” GHG emissions reductions may come from:

- » Attracting choice riders from private vehicles to public transit, through faster, more reliable, more comfortable, and safer service; and
- » Ensuring that existing transit riders do not switch to private vehicles as their income increases, by keeping public transport as attractive as possible.

“Improve” GHG emissions reductions can be achieved by:

- » Improving the efficiency of bus operations by reducing traffic delays and increasing travel speeds; and
- » Reducing fuel consumption by replacing older transit vehicles with newer, more efficient vehicles.

Figure 11. Metrobús: Mexico City BRT System – Ramiro Alberto Ríos



Public transport operational improvements

Transit operational improvements aim to improve service efficiency, reduce route travel times, and increase the reliability of time schedules through both roadway and transit infrastructure and operations. Roadway infrastructure and operations changes to benefit transit include green light priority for buses, queue jumping at intersections, the conversion of shared road space to dedicated bus lanes, and placement of stops so that buses can easily re-enter traffic. Operational improvements that can be implemented through the transit system only, include off-board fare collection systems, limited-stop service, and better schedule/headway control using Global Positioning Systems (GPS). Improvements should first be made in priority corridors with high levels of transit service and ridership.

Different analysis tools may be required depending upon the strategy. Transit ridership elasticities (which are embedded in sketch models such as TEEMP) can be used to evaluate the impacts of travel time savings. Average speed emission factors or traffic simulation models can be used to evaluate the emissions benefits of more efficient roadway operations.

Transit fare system improvements

There are many options to improve public transport fare systems, including fare integration and introduction of or expansion in the use of pre-paid fare instruments. Fare integration is the process of simplifying the payment process, using a common form of payment among the different public transit operators in a given city.

Transit fare improvements can reduce GHG emissions by increasing ridership as a result of time and monetary savings for riders. Travel behavior is affected not only by how much people pay, but also by how and how often they pay. Greater use of pre-paid fare instruments helps people feel better about paying public transport fares, as customers do not think so much about the cost when using fare cards. Such instruments also speed boarding and alighting, enabling public transport vehicles to travel faster and more reliably.

Evaluating the GHG impact is not entirely straightforward, as the behavioral effects of shifting from cash payment to prepaid boarding instruments are not entirely reflected in traditional fare elasticity analysis. Impacts are composed of ridership changes due to perceived pricing changes, with fare elasticities varying widely depending on income and service characteristics and the character and cost of competing travel opportunities in an area. When fare system changes increase average travel speed, schedule adherence, and reliability, these can have a significant behavioral impact as well as reducing emissions by cutting dwell times at stations. These impacts can be analyzed using elasticities of ridership with respect to travel time.



Public transport system integration in priority corridors

Public transport system integration demands better system planning and organization among the various operators in a metropolitan area. A multiplicity of uncoordinated bus and paratransit operations in a metro area typically leads to large inefficiencies, redundant and poorly used capacity, traffic congestion, hyper-competition between undercapitalized operators, poorly maintained vehicles, and inadequate supporting infrastructure, all of which results in higher levels of pollution and fuel use as well as poor service and economic performance. System integration presents opportunities to address all of these problems.

Evaluating the emissions impacts of public transport system integration ideally requires the use of a regional public transport and traffic model, although sketch analysis methods could be used to more crudely estimate impacts. System integration is likely to lead to both direct changes in average traffic speeds, congestion, and delay, and indirect changes in the attractiveness and ridership of public transport, as choice public transport riders are drawn to improved services. It may also lead to improvements in the vehicle fleet, which can be evaluated using fuel efficiency rates specific to different types and ages of vehicles.

Bus Rapid Transit

Bus Rapid Transit is a high-quality bus-based public transport system that delivers fast, comfortable, and low-cost urban mobility through the implementation of segregated busways with characteristics conducive to maximizing system efficiency. Some of the most important characteristics of BRT are: segregated bus ways, pre-boarding fare collection, platform-level boarding, fast and frequent operations, and good marketing and customer service. It is designed to provide transportation services similar to rail but with lower capital and operation costs and more flexibility.

There are multiple modalities by which BRT systems affect GHG emissions: the elimination of excess supply of old inefficient buses, increase in bus and mixed traffic average speeds, changes in mode shares by various modes and related changes in VKT, changes in fleet composition, vehicle load factors, and in the long run, changes in trip distribution and land use patterns. Ideally BRT impacts are evaluated using a travel demand model. However, sketch-level techniques are available that rely on elasticities (travel time improvements or cost savings) or experience from other BRT systems implemented in a variety of contexts. The TEEMP tool includes worksheets for BRT that allow for different levels of user data input. The CDM approved methodologies for BRT projects (AM0031) and mass rapid transit projects (ACM0016) have more stringent requirements that include extensive local data collection, as discussed in Part IV of this document.

Light rail, metro rail, and commuter rail systems

Rail transportation is a type of mass rapid transit that operates on fixed tracks. Mass rail options include streetcars, Light Rail Transit (LRT), Metro Rail Transit, and commuter rail services.

The GHG savings from rail come from shifting travel from buses, paratransit vehicles, and cars into less carbon intensive rail modes. The GHG emissions reductions depend in part on the source of electricity for rail propulsion and what happens to street space that may become less intensively crowded due to new rail services. Savings can be decreased significantly in the short run by the large GHG emissions from building rail transport projects, especially for underground metros, which may take several years to offset these emissions through comparatively lower GHG emissions during operation. In the longer term, rail investments can prompt significant transit-oriented development that further reduces GHG emissions.

The planning of large and expensive rail systems usually demands creation of regional travel demand models that can then support effective GHG analysis. However, the TEEMP model also provides a railway sketch evaluation tool to estimate ex-ante CO₂ impacts of urban rail projects in regions that lack good models for initial analysis. The CDM approved methodology for mass rapid transit projects (ACM0016) has stringent requirements that include extensive local data collection, as discussed in Part IV of this document.

Bus useful life regulation and vehicle phase-out, and vehicle scrappage programs

Vehicle retirement programs (implemented by regulation or incentives) aim to encourage bus operators to invest in the renovation of bus fleets. These programs can provide cleaner and more efficient vehicles.

Although useful life and vehicle scrappage programs should not impact VKT, they should reduce GHG emissions. Older buses are typically heavier, less aerodynamic, and consume higher amounts of fuel. As a result, the emissions per kilometer traveled are higher than newer buses. Newer buses can also be more efficient by carrying more passengers per vehicle. Advanced-technology vehicles, such as hybrid or electric vehicles can further reduce the fuel consumption and related GHG emissions from mass transit vehicles. Estimating the GHG impacts of such programs is fairly straightforward theoretically, considering the application of appropriate fuel economy or emission factors to scrapped and replacement vehicles. If fewer but larger replacement vehicles are used, adjustment should be made for load factors to determine GHG emissions per passenger-km. However, fuel economy measurements may be required to better estimate GHG emissions from new and scrapped vehicles.

Non-motorized transportation policies

Non-motorized travel improvements are a “shift” strategy as they encourage people to shift trips from motorized to non-motorized modes. Non-motorized improvements can reduce GHG emissions through the preservation of transportation modal habits – keeping more people walking and biking for a larger share of their trips. Improvements in pedestrian and bicycle networks can also attract more people to walk, bicycle, and ride public transportation. When long-term transport trends point to decreasing use of walking and cycling in the face of growing motorization – as is commonly the pattern in Latin American cities – then strategies that simply stabilize the NMT mode share can reduce GHG emissions when compared to this dynamic baseline. Such emission impacts can become quite substantial over time.¹⁶ Table 5 shows current non-motorized mode shares for major Latin American cities. Non-motorized travel is a major contributor to travel, making up one-quarter to 40 percent of all trips in most cities. This can be compared with 5 to 10 percent in a typical heavily-motorized city in the North America.¹⁷

Non-motorized improvements are discussed in the following categories:

- » Pedestrian infrastructure;
- » Traffic calming; and
- » Bicycle infrastructure, networks, and support programs.

Table 5. Share of daily trips by walking and bicycling in Latin American cities, 2007

METROPOLITAN REGION	PERCENTAGE OF TRIPS
Belo Horizonte	36 %
Bogota	18 %
Buenos Aires	9 %
Caracas	18 %
Mexico City	25 %
Curitiba	42 %
Guadalajara	39 %
Leon	39 %
Lima	26 %
Montevideo	27 %
Porto Alegre	32 %
Rio de Janeiro	37 %
San Jose	24 %
Santiago	37 %
Sao Paulo	35 %

Source: CAF -Observatorio de Movilidad Urbana (2009)

New and improved sidewalks and pedestrian crossings

Even motorized trips begin and end with walking, yet pedestrian infrastructure is in poor shape in many developing cities, making it uncomfortable or unsafe to walk to destinations or to access transit stops and stations. New or reconstructed sidewalks, as well as pedestrian crossings at intersections and mid-block locations where needed, can be important determinants for retaining walking trips as cities motorize. Sidewalks and crossings should meet accessibility guidelines in order to service all users including wheelchairs, strollers,

16 – GEF Scientific and Technical Advisory Panel. (2011)23 U.S. Bureau of Transportation Statistics, (2009). National Household Travel Survey
17 – U.S. Bureau of Transportation Statistics. (2009)

bicyclists, and others in need of a smooth, level surface. Introducing sidewalks of adequate width (ideally set back from the street curb with a buffer), marked or signalized pedestrian crossings, trees for shade, and ample lighting can add comfort to pedestrian trips. Enhancing these features can lead to an increase in the percentage of trips that are made by walking and transit. Improvements to streets within ½ to 1 km of transit stops, schools, and business districts should especially be prioritized.

Pedestrian improvements can have medium VKT and GHG reduction benefits if implemented as part of a city-wide program of improvements along with supportive land use strategies that encourage pedestrian-friendly development, although benefits of isolated improvements will be smaller. It is difficult to evaluate pedestrian improvements using most regional travel models, which have too coarse a spatial grain to well represent short trips and non-motorized travel. However, a growing number of models have been designed or modified to include “pedestrian environment factors” that provide sensitivity to NMT improvements. Micro-simulation models for both traffic and travel behavior offer the potential for sensitivity to how urban and street design factors affect travel behavior and traffic system performance, but again only if these are built into the model specifications, data collection elements, and model application environment.

In the absence of NMT-sensitive models, the TEEMP model package includes a module that can be used to evaluate the walkability of an area and to estimate at a sketch level how changes in walkability might translate into changes in CO₂ and other pollutants. Research in North America has also developed elasticities of walk trips, mode share, or VKT with respect to pedestrian design factors.¹⁸

Traffic calming

Traffic calming refers to the implementation of certain street design features and strategies that promote lower vehicle speeds and volumes. The construction of median refuges and bulb-outs, making street crossings shorter and safer for pedestrians and bicyclists, and the construction of speed humps and raised crosswalks are all examples of measures used to slow traffic. Implementing traffic calming features is important when promoting pedestrian safety, comfort, and accessibility along high volume streets. Traffic calming strategies also ensure that people who walk or bike keep using non-motorized forms of transport to complete their daily trips, given that pedestrians and bicyclists can feel more comfortable and secure if traffic speeds are reduced.

Traffic calming measures can have a medium-level potential for GHG mitigation, but only if they are done on an area-wide basis in ways that spur modal shifts and result in constant, moderate speeds, and as part of other pedestrian improvements. The CO₂ reduction benefit of traffic calming can be eliminated or reversed if drivers engage in aggressive slow down-speed up behavior in areas subject to such strategies. Isolated traffic calming may increase emissions. One study found that introduction of six speed humps on a road previously operating at 40km/h road led to a boost in fuel consumption from 7.9 to 10 liters per 100 km, with a resulting 27% increase in CO₂ emissions.¹⁹

Evaluating the impact of proposed traffic calming measures for their GHG impact needs to take these multiple factors into account. Traffic simulation models can be used to evaluate traffic calming, but the data and institutional capacity resources required to do such evaluation for a given area are considerable, and challenges may still

18 – Ewing, R., and R. Cervero. (2010)

19 – Quoted in Daily Express (London), October 1995. Cited by Litman, T. (1999)



be faced in accounting for the behavioral mode shift benefits of wide area traffic calming. Evaluation based on experience in comparable communities can serve as a rough guide to the likely impacts.

Improved bicycle infrastructure, networks, and supporting facilities

While many Latin American cities have high NMT mode shares, the share of trips by walking and cycling is falling in many cities due to increasing motorization and rising income, as motor traffic pushes cyclists and pedestrians into the ditch or squeezes them onto ever-narrowing passageways not filled with cars or motorcycles. In these circumstances, introducing high quality legitimate right-of-way and accommodations for bicycle traffic can make a real difference in long-term trends of bicycle use.

Infrastructure improvements include the construction of new bike paths and trails, cycle tracks, bike lanes, bike routes, and other types of roadway sharing. In many cities in developed countries, the idea of “complete streets” is adopted, to provide safe and comfortable accommodations for all modes of transportation, with a focus on NMT. Other important improvements to support cycling include secure parking facilities, both on the street and integrated into buildings; showers and lockers at workplaces; integration of bikes with transit through parking at stations and policies and equipment regarding carrying bikes on transit vehicles; bike-share programs; information on cycling routes and safe cycling practices; and enforcement of traffic laws for both motorists and cyclists. Master planning can ensure that improvements are prioritized and coordinated. For example, in Guadalajara, Mexico, the regional government has

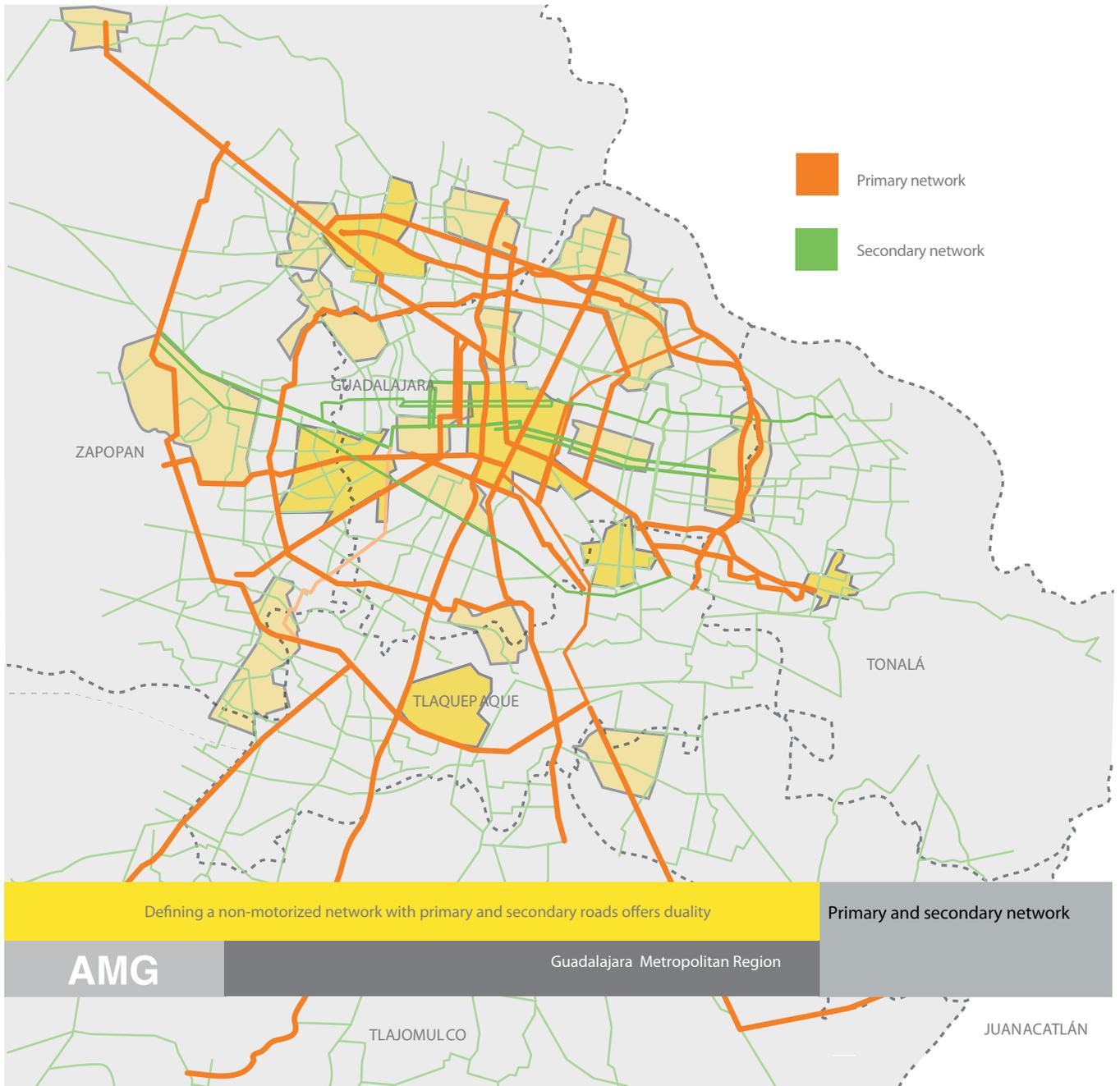
released a NMT master plan proposing a bike path and bike route network of 1,500 km throughout the metropolitan area (Figure 12).

The GHG emissions reduction potential of construction of bicycle transportation networks and supporting facilities in urban areas depends on the level and the quality of implementation of the cyclist infrastructure. Large, complete and integrated non-motorized mobility plans can effectively attract NMT trips from different types of motorized transportation and provide medium GHG emissions reductions in the long-run. Benefits will also be greater if network improvements are implemented in conjunction with supporting infrastructure (such as parking, transit integration, and bike-sharing) and policies (such as education and enforcement of traffic laws).

Modeling bicycle travel and the benefits of bicycle facilities can be a challenge. Impacts will vary greatly depending upon the quality and extent of facilities, land use context (e.g., trip density), attractiveness of alternatives (e.g., parking costs and traffic congestion), climate, and even cultural factors. Evaluation of the GHG impact of individual investments can be made by estimating the likely modal diversion from other modes and the degree to which the investment might help prevent existing cyclists from switching to more polluting modes. The analysis should consider that bike-transit trips may replace automobile park-and-ride trips that involve short-distance low fuel economy, high emissions per VKT travel. This means that CO₂ and other emission reductions are often disproportionately higher than VKT reductions. As an alternative to project-level analysis, GHG benefits of a city-wide program of bicycle investments may be estimated by examining other cities that have implemented similar programs.

NON-MOTORIZED URBAN MOBILITY MASTER PLAN FOR THE GUADALAJARA METROPOLITAN REGION

(figure 12)



Source: ITDP Mexico (2012)



Most regional travel models fail to represent bicycle trips, which like walking trips are not as easily represented in the coarse zone geography of aggregate models. Micro-simulation models have potential for heightened sensitivity to non-motorized travel, only if such travel is included from the beginning stages of data collection and on into model specification and development. In the absence of sensitive regional models, the TEEMP model includes a module for bicycle facility development sketch impact analysis. It is estimated that for every kilometer of wide

bikeway infrastructure constructed there is a potential to reduce CO₂ emissions by 250 tons per year, which is most likely to be realized in areas of denser travel demand.²⁰ The benefits of programs such as bicycle sharing or parking at rail stations may be estimated by looking at experience from other areas along with potential local market size and program deployment. For example, in Guangzhou, China, the implementation of a bike sharing system with 18 stations and 15,000 bikes has saved an estimated 1,365 tons of CO₂ in 2009–2010.²¹

Pricing motor vehicle use

As part of sustainable transport programs, ideal pricing strategies expand on the “polluter pays” principle, in which the party responsible for producing pollution is responsible for paying for the damage done. Efficient transport pricing offers unparalleled promise to manage existing road networks for high efficiency. By cutting congestion delay and achieving more optimal speed of operations, this can deliver substantial GHG reductions, while reducing congestion-related economic losses that typically amount to 2–3% of GDP. Such pricing can also generate considerable revenue to maintain high quality road network operations and to enhance the quality and attractiveness of sustainable transport options, especially for those who are priced off of road networks. Types of pricing strategies discussed in this section include:

- » Motor fuel taxes and subsidies;
- » Road user fees and tolls;
- » Congestion pricing; and
- » Cordon pricing.

All of these strategies affect the per-kilometer cost of motor vehicle travel. Other sections of this document also discuss parking pricing (under Parking Management), which affects the cost per trip, and vehicle excise fees and taxes (under Motor Vehicle Ownership and Use), which affect the cost of owning a vehicle.

Pricing has elements of all three GHG reduction mechanisms: Avoid, Shift, and Improve. Making travel more expensive causes travelers to forgo some trips (primarily trips with the lowest-utility). By assessing the traveler the full cost of motorized travel, it encourages the use of other, less costly modes. Finally, when implemented in situations that reduce congestion it can improve fuel efficiency by keeping traffic flowing at more efficient speeds.

The GHG impacts of pricing strategies are typically calculated by evaluating the elasticity of travel demand with respect to a change in pricing and then analyzing how that change in demand affects traffic volume, speed, and related emissions. This can be done relatively simply

20 – Bikeway TEEMP model default value.
21 – Hughes, C. and Zhu, X. (2011)

through the application of price elasticities of travel (e.g., change in VKT with respect to change in cost per km). More sophisticated micro-simulation models can evaluate the different ways in which travelers respond, including shifting modes, destinations, time of day, and even not taking trips. They can also account for differences in response among income groups. Aggregate models (which are based on average travel behavior across groups, such as all residents of statistical area such census tract) tend to do less well in recognizing the highly variable price sensitivity of different income groups.

Motor fuel taxes and subsidies

In many countries, fuel taxes are the main source of revenue for building transportation infrastructure and other transportation network improvements. In addition to raising revenue, fuel taxes can also discourage many single-driver trips, incentivize the use of alternative modes of transport, and reduce overall car use. Fuel taxes may be levied by national, state, or city governments. In the United States, there is a federal, a state, and a county sales tax. For instance, in California drivers pay a federal gasoline tax of US\$12.9 cents per liter, a state tax of US\$4.8 cents per liter, and an additional sales tax (which varies by county). Current fuel taxes vary widely by country. For example, in Latin America, Perú, Brazil, and Costa Rica have very high gasoline taxes while Venezuela and Ecuador offer large gasoline subsidies.

The GHG impacts of fuel taxes can be evaluated using elasticities that relate the amount of driving to the price of fuel. Elasticities are generally developed for both short-term and long-term impacts. Short-term impacts reflect first-order changes such as mode shifts and reduced

trips, whereas long-term impacts also reflect second-order changes such as changes in land use patterns and vehicle ownership.

Road pricing

Road pricing refers to direct payment by drivers for the use of a road or a road segment. Road pricing is often used to generate revenue to pay for road network investment and maintenance or other transport services. However, it can also be used to manage traffic congestion and to reduce GHG emissions, by shifting motorized trips to times of less demand, reducing traffic volumes, and improving network traffic performance. Toll roads are a common form of road pricing, and these schemes often charge motorists based on the distance traveled on the toll road. Distance-based fees (VKT fees) are recently being considered in some countries as an alternative revenue source to fuel taxes.

Where road tolls are used simply to build new capacity, they generally induce more traffic and GHG emissions, even while they likely generate less new traffic and emissions than would an equivalent unpriced road facility (had it been built, e.g., relying on general government revenues). Though the building of new toll roads is generally not an effective sustainable transport strategy, application of pricing to existing road capacity, alone or in conjunction with modest amounts of new managed road capacity, can help cut fuel use and GHG emissions.

Evaluation of GHG impacts of road tolls can rely on regional travel models, but care must be taken that these are capable of accurately reflecting price effects, and also that they incorporate induced demand impacts from any new facility construction. There are also sketch



analysis tools, such as SMITE, available from the US Federal Highway Administration, which account for induced traffic effects.²² The TEEMP model also contains a simple road GHG impact analysis tool. Pricing can also be evaluated more simply by using elasticities of vehicle-travel with respect to cost. However, it must be taken into account for any offsetting traffic diversion effects, if pricing is applied only on specific facilities.

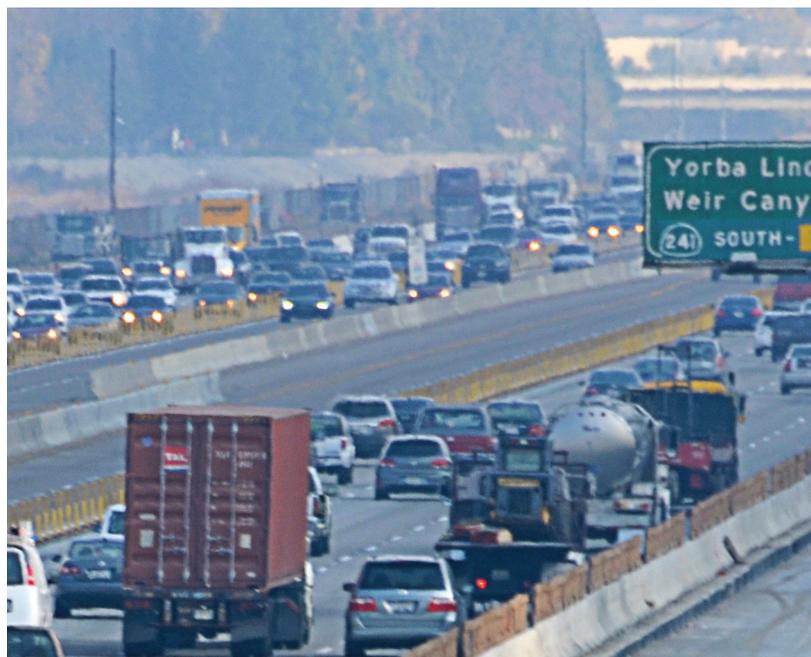
Congestion pricing

Congestion pricing is a travel demand management strategy applied to reduce traffic congestion by charging motorists based on the level of congestion on a road segment. The main difference between congestion pricing and a toll road scheme is that in the former, toll prices increase as demand for a facility increases, rather than a fixed cost. Congestion pricing, when applied appropriately, aims to manage traffic by smoothing traffic flow, encouraging travel to shift to less congested times of day, or to other routes or modes of travel, such as public transportation. Figure 13 shows State Route (SR) 91 in southern California, United States, where the centered lanes are congestion-priced, and the outer lanes are not priced. Congestion pricing is sometimes employed in “managed lanes,” which are priced facilities that operate parallel to unpriced facilities, giving motorists who are able and willing to pay a higher level of service while financing road improvements for all users.

To-date, congestion pricing has been implemented almost exclusively on an individual facility/roadway basis. In 1998, Singapore became the first city in the world to adopt fully Electronic Road Pricing (ERP). This enabled peak pricing charges to be reduced while extending them to most of the day and eventually to

more than 70 locations on the arterial and motorway network. Congestion pricing of whole networks, as in Singapore, typically yields significant travel behavior and network benefits resulting in GHG emissions reductions. Congestion pricing only of selected facilities, however, may in some cases increase GHG emissions. If the priced facility adds new capacity to the network, induced demand may result. For example, a 1999 evaluation of SR 91 estimated that if the new managed lane facility had not been built, VKT would have been 8% lower and modeled emissions of criteria pollutants would have been 18% lower. Congestion pricing of only certain facilities may also lead to increased emissions on unpriced and unmanaged parallel facilities, even if emissions on the priced facility are decreased.

Figure 13. Traffic on a Friday afternoon – Robert Chevez



22 – DeCorla-Souza, Patrick (2003)

While price elasticities of travel can be used for a first-cut sketch analysis, proper evaluation of congestion pricing requires travel demand models that have been calibrated for price response and include a time-of-day model. Reflecting time-of-day impacts is a particular challenge for analysis of congestion pricing, since some of the most significant impacts come from travelers taking trips at different times, in addition to shifting modes, forgoing trips altogether, or driving on unpriced facilities. Furthermore, congestion pricing has significant impacts on traffic flow. The resulting effect on GHG emissions can be captured through speed-based emission factors or through a traffic simulation model applied to the corridor which is being priced. Because of the wide variation in response that depends upon the nature of the pricing scheme and alternatives available to travelers, it is difficult to generalize about the impacts of congestion pricing just by examining experiences from other areas.

Cordon pricing

Cordon pricing is a form of congestion charging that imposes a fee to enter (or drive through) a congested area, often at the perimeter of a city center. Different variations on cordon pricing are used in London, Stockholm, Singapore, Milan, four Norwegian cities including Oslo, and other cities. The London congestion charge cut GHGs and air pollution significantly, initially by approximately 16% within the charging zone and 2–3% region-wide for GHGs, although benefits have decreased somewhat as traffic has increased over time.²³ In Latin American cities, cordon pricing could be applied to busy Central Business Districts (CBDs). It is under consideration in Sao Paulo and several other cities, but as everywhere, it faces potentially significant political implementation challenges.

Evaluating the GHG potential of any particular cordon pricing proposal requires sophisticated modeling using regional transport models, due to the complexity of response – including mode-shifting, route-shifting, time of day shifting, and forgoing trips. However, the experience of other cities can serve as a guide.

23 – Transport for London. (2008)



Land use strategies

The measures presented in this section aim to transform cities to achieve more efficient land use patterns. These strategies discourage automobile use as the main source of transportation by reducing trip lengths and making trips for walking, bicycling, and public transit easier and more comfortable. GHG-reducing travel impacts largely fall into the “Shift” category, but existing automobile trips may also be shortened and in some cases avoided.

Compact city development, also known as smart growth, is a combination of different types of development including: walkable communities, Transit-Oriented Development (TOD), mixed-use development, new urbanist neighborhoods (replicating pre-automobile forms of development), and infill development (as an alternative to development on “greenfields” far from the city). Land use strategies discussed in this section include: planning codes and practices, TOD, and car free zones and activities. Effective implementation of land use strategies requires coordination with a particularly broad range of stakeholders including planners, developers, lenders, property owners, local business organizations, local activists and local residents.

Urban planning codes and practices

Urban planning and land use policies can be used generally to manage travel by affecting future development patterns and ensuring that such new developments do not make people dependent on the use of the automobile. The effects of urban planning codes and practices to reduce travel and cut GHG emissions should be considered at three scales:

- » The arrangement of land uses at a regional or city-wide scale;
- » The site and subarea level, private property and buildings, as well as roads and pedestrian infrastructure internal to private developments; and
- » The public realm (streets and sidewalks).

At a city-wide level, achieving a balance of jobs and housing in areas through the city can lead to shorter trip lengths than segregating these uses or having residential areas located far from job centers. Shorter trip lengths not only reduce energy consumption per (motorized) trip, but also make transit and non-motorized modes more viable.

At the site or subarea level, requirements or incentives for minimal building setbacks, short blocks, and “active” street-fronting uses (instead of blank walls) all create a more pedestrian-friendly environment. Higher development density and mixed-use zoning effectively reduce average trip distances between people's origins and destinations by allowing both housing and commercial development within short distances or in the same buildings. They also make transit, walking, and bicycling more viable by creating shorter trip lengths and a high enough number of trips to support frequent transit service.

The design of public and private street space, including roads and sidewalks, has an important impact on travel choices because it affects the safety and comfort of pedestrians, bicyclists, and transit riders. Overly wide streets lacking central medians, for example, make streets hard to cross and often squeeze out space for

sidewalks or cycle paths. “Skinny streets” are more conducive to traffic calming. “Complete street” design standards, aimed at serving pedestrians, cyclists, public transport vehicles, and private cars, can ensure viable and safe mobility options for all.

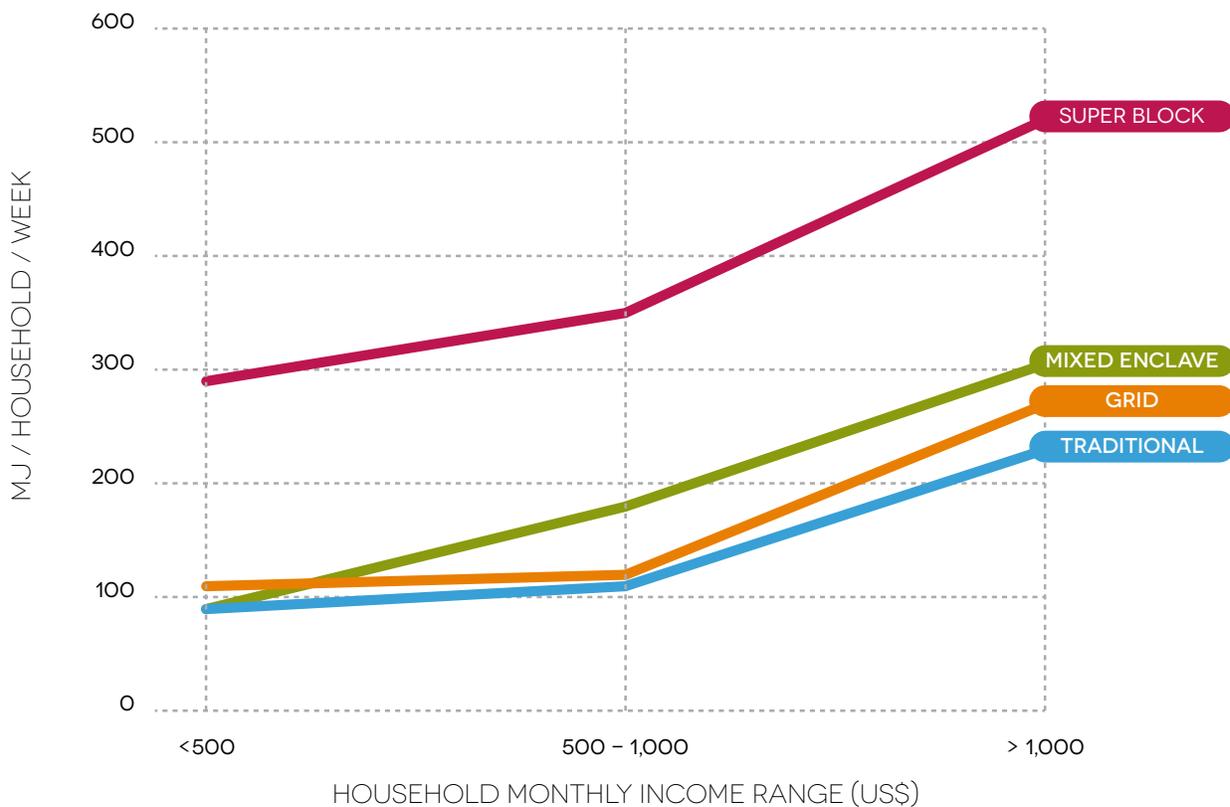
City planning and design strategies can also improve connectivity. It is vital that block sizes be constrained and connectivity requirements adopted to make more permeable, walkable neighborhoods. Where one finds superblocks and gated communities, pedestrians typically are forced to walk long distances out of their way to get where they need to go. Figure 14 compares findings from

one study of household energy use in different types of developments, with superblock developments showing much higher energy use than more traditional types with smaller blocks and greater connectivity. In areas near major public transport nodes, the introduction of diagonal pedestrian and bicycle access ways and other shortcuts leading directly to those station nodes can expand the market area for public transportation.

Within the same income range, household in the superblock neighborhoods consume much more energy in travel than other neighborhood types.

HOUSEHOLD WEEKLY ENERGY USE BY INCOME BY NEIGHBORHOOD TYPE IN JINAN, CHINA

(figure 14)



SOURCE: JING, YANG; DAIZONG LIU; AND SUPING CHEN (2011)

In the long run, land use planning is one of the most effective ways of reducing VKT and GHG emissions. GHG evaluation of urban design factors must be cognizant of the various interactions, drawing on the available research and when possible, adapting it with similar local studies. Micro-simulation models may one day better address these issues, as the costs of automated data acquisition, image processing, and related analysis continue to decline, but for now such methods are generally too data intensive in their requirements to be practically used on a day-to-day basis for GHG analysis of land use patterns, especially at the regional level. In the meantime, simplifications such as pedestrian environment factors can capture much of the design code-travel behavior interactions that determine travel GHG intensity. Literature (mostly from developed countries) has identified elasticities of travel (VKT, vehicle-trips, or mode shares) with respect to multiple built environment variables, including density, mix of uses, and design factors such as average block size.²⁴

Transit-oriented development

There is significant lock-in of long-term transport dependence on whatever transport mode is dominant at the time of urbanization. When an area develops around the automobile, it becomes difficult to provide a highly walkable and public transport-friendly environment. When an area develops around public transport, with greater reliance on walking and cycling, it becomes easier to sustain these models of travel over the long-haul. TOD's main characteristic is represented by compact development with high-densities and mixed-use development within short walk distances between 0.4 and 0.8 kilometers from major transit stations.²⁵

GHG emissions reduction benefits from TOD are estimated in the mid-term at a moderate level, although long-term impacts are large and profound if TOD is accomplished on a wide scale in conjunction with a high-capacity transit system. Evaluating GHG emissions reduction benefits of TOD may be done by using travel demand forecasting or integrated transport-land use models that have been estimated to be sensitive to urban design factors. In many cases, however, sufficiently sensitive models will not exist. There are also sketch tools and transferable parameters that evaluate these impacts, mostly by comparing experience in various metropolitan areas.²⁶ If mode shares or transit ridership per capita in an existing transit corridor can be observed, inferences can be made about the likely travel behavior of new residents and workers in TODs.



Figure 15. Transit-oriented development in Bogotá, Colombia – *Carlos Felipe Pardo*

24 – Ewing and Cervero. (2010)

25 – Rubin. (2007)

26 – Ewing, R., et. al. (2007)

Car-free zones and restricted traffic streets

Car free zones, also called “pedestrian only” areas, are neighborhoods with restricted car use. Many cities in Latin America have pedestrian-friendly city centers, which are optimal for the reduction or elimination of car use. In addition to car free zones, many cities around the world also implement car free events such as Ciclovía in Bogota, Colombia. According to Ciclovías Recreativas de las Américas, nearly 40 cities in Latin America hold weekly car free day events²⁷ to promote physical activity and to use public spaces and main transportation arteries

for recreational purposes. During these events city streets are closed to automobile circulation and people are encouraged to bike, walk, skate, jog, and carry out many other recreational activities.

Car free streets and events provide a modest GHG emissions reduction benefit. Evaluating the GHG impact of these events can be done by considering direct emission reductions from estimated traffic reductions. There are probably additional indirect benefits that come from positive changes associated with public attitude shifts towards NMT. These are harder to quantify, but could be evaluated through attitudinal surveys.

Parking pricing and management

Parking is an extremely important link between transportation and land use. The average car remains parked 95% of the time,²⁸ which makes parking one of the most important land uses in any particular city. Managing parking requires the implementation of a number of specific parking strategies. Parking management measures lead to a more efficient use of public space designed for parking and also serve as a means of encouraging people to use alternative modes of transportation. A variety of parking management strategies can be implemented to reduce vehicle travel and divert some trips to cleaner transport modes. Parking management strategies can also help recover investment costs and are widely used for revenue generation in many cities in developed countries. Parking management strategies discussed below include:

- » Parking pricing, which refers to setting the right price for parking, necessary to achieve the most efficient transportation network;
- » Managing the supply of on-street parking, which also contributes to the efficiency of the transportation network by setting the number of parking spaces that would maximize the effectiveness of the space used for parking; and
- » Setting parking requirements for buildings and other land uses, to reduce the number of parking spaces planners require for a given type of land use.

27 – Ciclovías Recreativas de las Américas 2011, <http://www.cicloviasunidas.org>
28 – Shoup. (2005)



Parking pricing

In many developing countries most parking is provided free of charge. For example, business owners, employers, and even land developers can provide subsidized no-cost parking to customers; yet building, managing, and maintaining parking spaces is far from free. Parking pricing policies can have an important impact on reducing traffic congestion and vehicle circulation through local streets by ensuring users pay the direct costs associated with providing the service. Studies have shown that drivers searching for free on-street parking can account for one third of traffic along some urban streets.²⁹ On-street parking fees are applied to optimize the use of curb space, to determine the time drivers will be parked in a determined space, and also to reduce potential congestion caused by drivers looking for a parking space.³⁰

Sustainable mobility plans need to consider both on-street and off-street parking management and pricing strategies. While, the municipality can directly control pricing only of on-street spaces and municipal lots, taxes or fees can be applied to private spaces. Pricing can also be affected indirectly.

Some cities are requiring that parking spaces be sold or leased separately from residential or commercial units, allowing residents and businesses to save money if they purchase or lease less parking. Reducing parking supply (see next section) also helps to create a market for priced parking.

Parking pricing mechanisms can have a medium to high impact on travel reduction and GHG abatement, if they are implemented on a wide scale and if high-quality

alternatives to driving exist. Mode shifting is a primary impact, but not the only impact. Pricing may also affect car ownership decisions, which in turn have a profound impact on household travel behavior and mode choice. Pricing may also affect destination choice, especially if implemented only in limited areas where a choice of destinations exists (such as shopping malls). In such situations pricing may have unintended consequences, such as primarily shifting motor vehicle travel to other destinations where parking is not priced, rather than reducing it. These unintended consequences are likely to be greater for non-commute trips, where travelers may have more flexibility with respect to destinations.

Analyzing parking pricing in regional travel models requires the use of fairly sophisticated car-ownership, mode choice, and destination choice models. In the absence of such models, various sketch models and rules of thumb can suffice. For example, the cost of parking can be averaged over the cost of a trip, and an elasticity of VKT with respect to travel cost applied. This simplified analysis, however, does not account for shifting of motor vehicle trips to unpriced destinations or times of day.

Managing on-street parking supply

Cities can reduce or otherwise manage the supply of on-street parking, as well as pricing it correctly as discussed above. Parking pricing and supply management, in fact, go hand-in-hand. It is much more difficult to implement pricing when supply far exceeds demand. Parking management strategies that can work on their own or in conjunction with pricing include:

29 – Shoup. (2005)

30 – Kodransky, M. and Hermann, G. (2011)

- » Reducing the excess use of on-street space for parking that detracts from other uses of the street (e.g., parking on the sidewalk), through enforcement of parking regulations;
- » Implementing time limits (through meters or signs) in business districts to encourage turnover so that other customers can park;
- » Designating loading zones to keep vehicles from impeding the flow of traffic; and
- » Implementing static or dynamic signage and other information systems to inform drivers of available parking options.

Eliminating on-street parking in order to create additional traffic capacity is typically not an effective GHG reduction strategy, as it degrades the quality of the pedestrian environment and may lead to additional traffic due to induced demand effects. However, it may sometimes be necessary to eliminate some on-street parking in order to improve bicycle or pedestrian facilities, which can also reduce GHG emissions.

On-street parking management can result in a modest GHG emissions reduction benefit by itself, but parking management is also an important part of larger efforts along with land use, transit, and NMT to create more walkable cities. Direct supply restrictions or management are difficult to evaluate as they may have complicated effects that today's models are not well suited to evaluate. In some cases, sketch models, including the TDM module in the TEEMP package, may be used to evaluate parking strategy GHG impacts.

Establishing maximum or reducing minimum parking requirements

Capping the number of parking spaces in CBDs and regional employment/retail centers, and limiting the parking provided with any new development, can discourage single-driver vehicle trips, encouraging different modes of travel. High minimum parking requirements often lead to an over-supply of parking, driving down prices (but not the cost of providing parking) and encouraging automobile use. Simply reducing or eliminating minimum requirements can let the market determine what is necessary. Maximum parking requirements are being implemented in many cities to establish an upper limit to the number of parking spaces that can be constructed. This drives the price upwards, ensuring drivers internalize some of the costs related to the use of the automobile.

GHG emissions reductions gained through the reduction of minimum or establishment of maximum parking requirements vary depending on how comprehensive the policy is and whether high-quality travel alternatives are available. Such policies will have the greatest GHG benefits when implemented in conjunction with land use, transit, and non-motorized investment policies that make alternatives to driving feasible and attractive. It is challenging to model the impacts of parking limits on parking costs, travel, and GHG reductions. However, effectiveness may be evaluated over time by tracking parking prices and automobile mode shares for the affected areas.

Commuter travel reduction policies

Commuter travel reduction policies aim to reduce vehicle travel by giving employees incentives and options for commuting by different modes. There are a number of strategies employers or municipal governments can use to influence commuters' choices. The strategies discussed in this section include:

- » Alternative work schedules, flexible time schedules, compressed work weeks, and telework;
- » Rideshare matching and incentives; and
- » Tax incentives for alternative mode use and disincentives for employer provided free parking.

These strategies are most commonly found in developed countries and less often seen in lower income developing countries where crafts, industrial, agricultural, or extractive industry employment dominates. Implementing these types of policies should be considered for developing countries especially in areas where employment is growing in services, information, banking, finance, and office functions. These policies are starting to be appear in some places. For example, various non-profit organizations and university student groups in Mexico and Argentina have been organizing rideshare matching systems.

These strategies function through both the Avoid and Shift mechanisms. Their impact depends on the size of the worker market affected, characteristics of these workers and their jobs (including current commute mode and flexibility to change), and specific incentives or options given. Bundling strategies will result in higher benefits. These strategies cannot be easily evaluated using regional travel models. However, sketch analysis

methods for each of these strategies are available in the TEEMP toolbox and in other sketch tools developed in the United States and Europe, such as the COMMUTER and TRIMMS models.

Flexible time schedules

Also known as flextime, flexible time schedules allow employees to start and stop working within a flexible time frame. For instance, an employee may choose to work eight hours starting between 8:00 AM and 10:00 AM and concluding the workday between 4:00 PM and 6:00 PM. Flexible time schedules can be applied at many workplaces in the developing world, especially large organizations with large numbers of office workers and also in government facilities. While flextime does not reduce motor vehicle trips, it can shift trips from congested peak periods to less-congested off-peak periods, reducing GHG emissions through more efficient travel. The GHG benefits of flextime are likely to be modest and difficult to quantify. However, the cost of strategy is minimal and there can be significant benefits to employee satisfaction.

Compressed work weeks and telework

Teleworking means allowing employees to work from home and using technology and telecommunications to substitute for physically travelling to the workplace.

Compressed work weeks are schedules comprised of longer work days but shorter weeks. For example, there are two common schedules used by many companies in the United States, including federal government workers. The first option is to work 10 hour days and get one day off every week (a so-called “4/40” schedule). The second option is to work 9 hour days and receive one day off every two weeks (a so-called “9/80” schedule).

These strategies have similar effects by reducing one round-trip work trip every few days to two weeks for every participating worker. However, there may be a modest offsetting GHG impact resulting from additional non-work travel and home energy use on the employee’s day off. It is important to identify the types of jobs that are suitable for alternative work schedules. Telework is most suitable for office jobs, for workers who do not always need to be physically present at their worksite. While adoption of alternative work schedules is primarily driven by the private sector, public agencies can take the lead in offering such options to their employees, as well as offering technical assistance programs such as model telework policies and resources for technology needs.

The VKT and GHG benefits of telework and compressed workweeks are generally best analyzed by developing locally-specific estimates of the potential worker market affected, type of schedule, trip lengths, and prior mode shares. Sketch tools such as TEEMP, COMMUTER, and TRIMMS can assist with this analysis and provide default parameters based on experience in other countries.

Ride/share matching and incentives

Ridesharing refers to the organization of individuals to share a vehicle when commuting to and from work, also called carpooling and vanpooling. Usually a participant’s car is used for carpooling, while vanpooling generally uses rented vans supplied by employers or other specialized organizations.³¹ To facilitate ridesharing, local governments, large employers, or organizations of employers can establish rideshare-matching programs to match drivers and riders who live and work in nearby locations. Other incentives can also be provided, such as preferential parking or occasional prize drawings for registered carpool participants.

Ridesharing presents a significant opportunity to reduce VKT and also GHG emissions, as carpool automobiles would have higher number of passengers than they would generally have. The benefits will depend upon the extent to which carpoolers previously drove vs. used other modes. The effectiveness and benefits of ridesharing facilitation and promotion programs in Latin American countries have not been widely studied. The GHG benefits of ridesharing are best analyzed using locally-specific data on program impacts (rideshare matches and frequency), as well as prior mode shares and trip lengths. These can be determined through surveys of workers where ridesharing programs have been collected, before and after implementation.

31 – Victoria Transport Policy Institute TDM Encyclopedia, <http://www.vtpi.org>

Tax incentives for alternative mode use and disincentives for employer provided free parking

Providing subsidized parking encourages employees to drive to work as the price of parking is not internalized by the driver. In dense employment areas where there is a market value on parking, employers may encourage employees to opt-out of their parking spaces by offering “cash in lieu of parking” (also called parking cash-out), which acts as an incentive to employees to reduce vehicle use. Employer cash-out is managed directly by the employer, whether it is a government agency or a private corporation, and sometimes it is regulated by local or state laws. The government can encourage parking cash-out by taxing the full value of parking benefits provided, thus making it more expensive for the employer to provide a given benefit.

Tax incentives can also be provided to encourage use of mass transit, walking, or bicycling. For example, the United States tax code allows employers to provide up to US\$230 per month in transit subsidies as a pre-tax benefit. A similar credit could be provided, for example, for the provision of a monthly bicycle benefit. Finally, tax credits can be provided to businesses that provide telework equipment to their employees.

Since the traveler or employer is receiving a direct price signal, tax incentives and disincentives are effective ways of encouraging commuting by non-auto modes, potentially providing a medium level of VKT and GHG emissions reductions for work trips if widely implemented. The magnitude of the GHG benefit will be related to the monetary value of the incentive or disincentive, as well as the quality of alternatives available and the size of the worker market to which they are offered. Sketch-level methods such as TEEMP and the COMMUTER and TRIMMS models can be used to evaluate commute-based monetary incentives.

Motor vehicle access and use

This section includes a number of disincentives to car ownership and use and incentives for not owning cars. Strategies that function as disincentives to car ownership and use include raising motor vehicle excise taxes and fees, motor vehicle quota systems, and license plate restrictions that prohibit driving on certain days. In contrast to these “stick” approaches to limiting motor vehicle use, car sharing programs are also described, as a “carrot” to make it easier to achieve personal mobility without owning a car.

These strategies function through both the “Avoid” and “Shift” mechanisms. Households that do not own a motor vehicle (or only own one vehicle instead of two or three) may forgo some trips but also will take most of their trips by other, more sustainable modes. Strategies that restrict motor vehicle ownership and use may be difficult to implement because they are perceived as restricting mobility options, but this can be mitigated by investing revenues in improving alternative transport and providing vehicle mobility options through car-sharing.

Car-sharing programs

Car-sharing programs are membership-based programs in which members have access to vehicles parked in publicly-accessible locations nearby to their residence or workplace. Car-sharing can be implemented through for-profit entities, the creation of public-private partnerships, or a non-profit car sharing system.

Car-sharing programs can provide low to medium-range GHG benefits by reducing the need for individual car ownership without sacrificing mobility. Car-sharing internalizes the marginal costs of car use for those who rely on it, and the vehicle tends not to be at the immediate doorstep, so car-share users are conscious car consumers. While car-sharing has been shown to support reduced vehicle ownership and travel, some car-share members were not previously car owners and therefore travel more than they would have otherwise. This represents a valuable mobility benefit, but offsets some of the GHG savings of the program in the short run. In the long run, and compared to a dynamic baseline, car-sharing systems pose a solid GHG benefit as they can prevent some households to acquire private vehicles.

Travel models typically do not represent car-sharing, which still occupies a very small market niche even where it is more available, so existing research on car-sharing program benefits is likely the best starting place for estimating GHG benefits. For example, a recent study of car-sharing in North America found that the GHG emissions reduction per household participating in the system averaged between 0.58, and 0.84 tons per year.³² Each car-share vehicle is typically shared by 10 to 20 households, making more efficient use of street and parking space, which can have an indirect effect on GHG emissions by supporting a more pedestrian-friendly environment.

32 – Shaheen, S. and Elliot M. (2010)

Motor vehicle registration fees and taxes

In developed countries, automobile registration fees are assessed in a yearly (or bi-yearly) basis. Registration fees can be assessed depending on vehicle type (car, motorcycle, or commercial vehicle) year of manufacture, size, and fuel type consumed. A sales tax may also be levied on all vehicles purchased. Sales taxes can be used to encourage the purchase of newer and cleaner vehicles. For instance, local and regional governments can set hybrid vehicle taxes at a lower rate than other gasoline or diesel vehicles. Feebates can also be used to transfer incentive payments from those who purchase high fuel consumption vehicles to those purchasing more fuel efficient vehicles within the same class of vehicle.

Motor vehicle fees and taxes in Latin America present an opportunity to reduce vehicle activity and GHG emissions at low implementation costs, although high fee levels may face political challenges. VKT and GHG emissions reduction benefits will be in proportion to the size of the tax or fee levied. These strategies may be evaluated for their GHG impact using mathematical models of motor vehicle ownership, or elasticities of vehicle ownership with respect to cost. Experience from other feebate programs may also be used as a guide.

Motor vehicle quota systems

Developing countries demonstrate high motorization rates across much of the world. Car quota systems aim to control motor vehicle ownership by requiring a buyer to acquire a supplemental right to a motor vehicle

registration before purchasing a car. This strategy has been applied in Singapore, where the Vehicle Quota System (VQS) was implemented in 1990. In order to buy a car under the vehicle quota system, one must bid for and obtain a license or a Certificate of Entitlement (COE) to purchase a vehicle. Since 1998, Shanghai has also had a vehicle quota system in place, limiting the number of new registrations to 50,000 per year, with registrations sold at public auction. These cost roughly US\$5,000 each in 2006.

Vehicle quota systems offer a high potential for GHG emissions reduction, depending on how stringent the control and level of pricing, although they may be politically difficult to implement. Such quota systems often spur registration of vehicle at locations outside the jurisdiction, unless only locally registered vehicles are allowed to operate in some portions of the city, an approach being advanced in Beijing. The VKT and GHG benefits of quota systems can be determined by estimating the cost premium that will be imposed by the quota and applying elasticities of motor vehicle ownership with respect to cost; or by projecting the number of vehicles in operation

without vs. with the quota, and multiplying by average distance driven per vehicle.

License plate restrictions

License plate restrictions can be applied to limit the number of cars that can legally circulate in a city. The strategy prohibits vehicles with certain license plate numbers to circulate on one or more days of the week. In some cities the ban on car use can be effective during certain hours; however, in other cities the ban may apply to whole days. One of the most known license plate restriction programs in Latin America is “hoy no circula” in Mexico City. The program operates six days a week, reducing vehicle use by one-fifth at any given day, and is enforced in Mexico City as well as 18 neighboring municipalities.³³

License plate restriction schemes can achieve a medium GHG emissions reduction impact. These impacts may be estimated based on the number of vehicles affected per day and distance traveled per vehicle. They do in the long run prompt people to buy more cars, however, causing the measures to lose effectiveness over time.

System operations and management

System operations and management strategies intend to improve the efficiency of travel through operational changes that avoid fuel-wasting stops and starts and keep vehicles moving at moderate, efficient speeds, and by disseminating information to help train motorists on how to apply more efficient driving techniques. They typically are not directed at reducing vehicle travel, although in some cases they may have secondary effects of either increasing or reducing travel. Instead, they are focused on the “Improve” mechanism for reducing GHG

emissions. In general, system operations improvements are implemented by government agencies such as regional or city level transportation authorities. Efficient driving campaigns may also be implemented by national or state environmental protection bodies, as well as vehicle manufacturers and non-profits. Strategies described in this section include:

- » Reducing speed limits on motorways;
- » Eco-driving and vehicle maintenance programs, to

33 – México City Government, <http://www.df.gob.mx>

- help drivers operate vehicles more efficiently; and
- » ITS to improve the efficiency of the transport network.

Reduce national speed limits on motorways

In addition to being safer, lower speeds improve fuel efficiency and reduce GHG emissions from vehicle engine combustion. On freeways, average speeds above 100 km/h have a greater impact on GHG emissions.³⁴ Research has found that optimal average speeds for highways (for GHG emissions reduction purposes) lie between 50 and 80 km/h considering typical vehicle fleets in Latin American countries.

The GHG benefits of reduced speed limits can be evaluated knowing the volume of traffic that is affected, current average speeds, and the relationship between speed and fuel consumption or GHG emissions. Consideration also needs to be given to the level of enforcement provided and its effectiveness. If speed limits are not enforced, simply lowering the speed limit will provide little GHG benefit as few people will comply with the lower limit.

Eco-driving and vehicle maintenance programs

Eco-driving refers to a range of educational programs and technologies that assist motorists on the application of driving techniques that can lower vehicle fuel consumption in both passenger and freight vehicles. These fuel economy results are achieved by consciously driving at constant speeds, driving at speed limits, reducing rapid acceleration and deceleration events, in some cases

using cruise control to maintain a steady velocity, and changing gears appropriately. Eco-driving programs can also provide training on proper vehicle maintenance that includes information on optimal air pressure levels, oil types and wheel types. An important complement to education programs is to provide in-vehicle feedback devices (such as upshift lights or fuel economy meters) on new vehicles, which requires national regulation.

Applying moderate levels of eco-driving techniques, a private automobile driver should expect to reduce fuel consumption by about 15%.³⁵ A Canadian study estimates that many fleets could achieve a 10% fuel economy improvement through driver training and monitoring.³⁶ The GHG benefits will depend upon how broad a segment of the population is reached and adopts eco-driving practices. It is a challenge to reach a wide segment of the population, and also for people to retain the information and keep practicing eco-driving techniques over time. Some of the greatest benefits may be realized through programs focused on truck, bus, and public-sector automobile fleets, since eco-driving can result in fuel and monetary savings for vehicle and fleet operators and many drivers may be reached through a single training program. The TEEMP model contains a simple sketch model to estimate the benefits of eco-driving initiatives. These can also be examined using other specific tools tied to these program experiences.

Intelligent transportation systems

Intelligent Transportation Systems (ITS) refers to a number of information technology strategies that are used in both developed and developing nations to solve

34 – Barth and Boriboonsomsin. (2008), Otten and Van Essen. (2010)

35 – <http://www.ecodrivingusa.com>

36 – U.S. Environmental Protection Agency. (2013)



problems related to traffic congestion, and optimize the use of the transportation network. Common ITS strategies include:

- » Real-time traveler information, which are systems that allow travelers to make more informed decisions before or during their journey, by providing information on travel conditions and options by all modes;
- » Traffic signal timing, synchronization, and adaptive control, to reduce vehicle delay and move traffic more efficiently on arterial streets;
- » Incident management, to identify incidents more quickly, improve response times, and manage incident scenes more effectively;
- » Ramp metering, which uses traffic signals at motorway on-ramp intersections to manage traffic flow onto the motorway; and
- » Active traffic management and integrated corridor management, combinations of technologies to dynamically manage traffic flow and disseminate information to drivers along a roadway or set of parallel transportation facilities.

ITS can be used to effectively manage unexpected and difficult events such as traffic accidents and large special events. They can also reduce congestion during peak hours by ensuring that traffic controls operate the network as efficiently as possible, and by informing motorists of real-time road network conditions and alternative route information. Several ITS technologies are also found in road pricing schemes, system operations and management programs, and in public transportation buses and



Figure 16. Active traffic management scheme in Bangkok, Thailand – Carlos Felipe Pardo

stations. A central component of an ITS system is often a traffic management or operations center, through which information on traffic conditions is fed in real-time to engineers who can manage the system by adjusting traffic signal timing, providing information to travelers through various channels, and responding to incidents as they happen. Comprehensive ITS implementation requires coordination amongst a number of parties including municipal, state, and/or national road construction and operation authorities, transit operators, and emergency response personnel.

Since traffic improvements will make travel easier, they are likely to result in induced demand, which will erode the GHG benefits over time. Therefore, the GHG emissions reduction potential of most of these strategies is low to medium, unless introduced as part of area-wide congestion pricing, which can help to manage demand and ensure that the full benefits of ITS are realized.

The simplest way to estimate the GHG benefits of many ITS strategies is to estimate average speeds on a corridor before and after an improvement (such as signal

coordination), identify speed-based emission factors from a model such as the International Vehicle Emissions model, and apply these to the affected traffic volumes. Traffic simulation models can also be used to estimate fuel savings and GHG impacts, but these are not typically applied except in major projects because of the effort associated with data development and model application. Models of varying sophistication have been developed in the United States, such as the SCReening for ITS (SCRITS) spreadsheet tool and the ITS Deployment and Analysis System (IDAS), which works with travel demand models.

The GHG benefits of incident management and traveler information are especially difficult to quantify without a detailed evaluation of the program and conditions under which they are implemented. Without such an evaluation, benefits may be estimated from experience in other areas where they have been implemented. For example, an incident management program in San Antonio (United States) implemented with traveler information and dynamic message signs along a freeway corridor led to a 1.2% decrease in annual fuel consumption on this corridor.³⁷ Active traffic management and integrated corridor management are emerging strategies whose benefits have not been well studied, and again, are likely to vary by application.

Roadway capacity expansion or reduction

Roadway capacity programs aim to reduce congestion or pollution through a variety of techniques that expand roadway capacity and reduce bottlenecks, thereby improving traffic flow. Examples include building flyovers or underpasses, installing traffic signals and traffic signs, building traffic circles, or building a bypass around the edge of town to carry through traffic.

The direct GHG benefits of major roadway capacity expansion can be evaluated using traditional 4-step travel demand models. These models forecast traffic volumes and speeds by network link, which can be used along with speed-based fuel consumption or emission factors to predict fuel use and GHG emissions under different network scenarios. Traffic simulation models provide a more detailed assessment of intersection improvements. Project-level evaluation can also be conducted knowing “before” and “after” traffic speeds and volumes at different times of the day.

While roadway capacity expansion can result in improved traffic flow and GHG reduction benefits in the short-term, a growing viewpoint believes that implementing bottleneck relief or capacity expansion strategies in Latin America can be futile or counterproductive in the long run, given pressures of traffic growth, in addition to being difficult and costly. This is because additional provision of road space in congested areas tends to induce new demand.³⁸ Research over the past two decades shows that the elasticity of travel volume with respect to roadway capacity can range from roughly -0.2 to -0.5 in the short term and -0.4 to -0.9 over the long term, with some estimates even exceeding -1.0 . This means that increasing the capacity of a roadway by 20% typically increases traffic volumes by 4–10% in the short term and 8–18% or more over the long term.³⁹ Elasticity values in developing cities, such as Latin American cities, are likely to be at the high end of this range given the strong motorization pressures that these cities face.

37 – U.S. Department of Transportation, RITA. (2000)

38 – Cervero, Robert. (2002)

39 – Litman, Todd. (2010)



In response, some now argue for tearing down certain elevated roadways rather than building new ones. Researchers have in fact shown that when traffic capacity is reduced, traffic usually disappears to the extent it needs to do so to avoid unacceptably congested conditions. In two seminal studies, Goodwin, Hass-Klau, and Cairns looked at data on traffic volumes before and after roadway removals in ten countries in Asia, Europe, and North America. In many cases, there were significant reductions to the total amount of traffic on the networks studied over the long term, in the range of 14–25% of the traffic that previously used the affected route.⁴⁰

Aggregate 4-step travel models typically under represent the impacts of induced traffic because they are not sensitive to the full range of a traveler's decisions. Travel demand micro-simulation models typically have greater

sensitivity to such interactions if they are represented in the development of the analysis tools. Several sketch tools, such as the SMITE model from the U.S. Federal Highway Administration, offer capacity to represent these induced demand relationships and to calculate GHG and other emissions at a project level, offering a good complementary tool to aggregate travel models.⁴¹

There is general disagreement and limited evidence about the extent to which the benefits and impacts of capacity expansion offset each other with respect to GHG emissions. However, the Moving Cooler study in the United States, assuming moderate levels of induced demand, concluded that there was no net GHG benefit over the long term from reducing bottlenecks, considering induced demand effects.⁴² Higher levels of induced demand would imply a net increase in GHG emissions.

Multimodal freight strategies

Economic globalization, the growing demand for products, and current manufacturing trends are increasingly demanding the integration of freight modes. Multimodal freight strategies highlight the importance of the integration of more than one mode of transport (rail, truck, and airplane) to move freight from raw material sources to manufacturing locations to final consumption destinations. These interrelated freight relationships have become even more important since the introduction of the freight container. Governments play a major role in the provision and regulation of intermodal freight facilities. Freight intensive companies, truck drivers and wholesale consumers also play an important role on freight efficiency and service optimization. These players benefit from time and cost savings generated by greater efficiency along the supply chain. Such efficiencies can also result in GHG emissions reduction benefits.

There are many ways to improve freight systems to reduce emissions. Increased investment in multimodal freight infrastructure (including rail infrastructure as well as ports and intermodal terminals) can open up possibilities for transfers between trucks and less energy intensive modes such as rail, sea, and inland ships. Improved logistics systems and the introduction of regional freight distribution centers may facilitate transfers from half-empty large trucks to full small trucks, help minimize the circulation of empty trucks, and increase overall capacity utilization of truck and rail vehicles. Optimizing freight vehicle loads can cut freight costs and support sustainable transport system goals. Finally, pricing policies can be applied to help manage demand and provide incentives for cleaner and more efficient vehicles. Strategies discussed here include:

40 – Cairns, S., Hass-Klau, C., and Goodwin, P. (1998)

41 – U.S. Federal Highway Administration. (2011)

42 – Cambridge Systematics, Inc. (2009)

- » Enhancement of intermodal freight infrastructure;
- » Freight pricing and management; and
- » Regional freight distribution centers, inland ports, and logistics parks.

Enhancement of intermodal freight infrastructure

There is a potential in most countries for some shifting of freight from truck to rail and waterways using methods that are likely to reduce GHG emissions. While trucks are more flexible in where they can travel, rail freight has lower rolling resistance and aerodynamic drag, giving it greater energy efficiency and lower GHG emissions per ton-km. Waterborne freight uses even less energy per ton-km, although it is usually the slowest of these modes. Not all freight is amenable to mode shifting. Water and rail work best for bulk commodities, such as coal, oil, metal ores, and grain. High value finished goods most often travel by truck or air. To be effective, intermodal systems must be cost-effective for shippers and practical for haulers and freight forwarders.

Intermodal infrastructure improvements to encourage mode-shifting may include freight rail expansion and improvements (e.g., higher weight limits and bridge clearances to allow double-stack container traffic), construction of intermodal port infrastructure, and improved access to intermodal facilities. ITDP has used Roadmap,⁴³ a global vehicle stock and activity model, to consider the potential truck activity reduction (ton-km) that could result from mode shifts and improved logistic systems efficiency compared with BAU scenarios in various countries and regions around the world. Preliminary results show that implementing policies that shift 4% of truck activity to freight rail in Mexico and

Brazil could cut GHG emissions by 4-6 MtCO₂e by 2030. These impacts represent GHG emissions reductions of 1 to 4% of transport-related GHG emissions.

Travel demand models typically do not represent freight vehicles well and do not model the decisions of freight shippers and carriers like they model personal travel decisions. Usually, overall VKT is simply factored by the fraction of traffic by trucks as observed from traffic counts. Regional models also do not consider inter-regional freight flows, which is the scale at which most mode-shifting opportunities exist. Cost-minimization models have been developed in the United States and Europe to model intermodal freight choices over long-distance corridors, but they have not been widely used and may not be readily transferable to Latin American contexts.

Data is needed to develop more effective models of urban and intercity freight systems to support sustainable transport planning. Evaluating the GHG impact of intermodal freight measures typically requires national level vehicle stock models, as well as inventories of various freight modes and levels of activity. National data collection should ensure an understanding of current fleet characteristics, freight industry trends and structure, commodity and shipment flows, current freight vehicle capacity utilization, and freight pricing structures and policies.

43 – <http://theicct.org/roadmap-model>

Freight pricing and management

Freight transport produces a number of negative externalities in both urban and rural areas, such as congesting streets, degrading air quality and traffic safety, and placing disproportionate wear and tear on the roads. More appropriate pricing of freight to recover the full costs to society will lead to more efficient consumption and investment. Non-pricing management strategies can also be implemented. Examples of freight pricing and management strategies include:

- » Differentiated tolls and/or fuel taxes for road use, e.g. based on vehicle weight;
- » Time-based pricing schemes and other programs at congested ports to reduce truck queuing and idling emissions;
- » Time of day restrictions in congested areas, such as CBDs, to shift deliveries to off-peak hours;
- » Designated truck routes and truck traffic restrictions, to keep through trucks out of residential neighborhoods; and
- » Truck parking and loading zones to keep trucks from impeding the flow of traffic.

A few studies exist of GHG impacts from freight management. For example, pricing, time-of-day, and clean vehicle initiatives implemented at the Ports of Los Angeles and Long Beach (United States) were estimated to reduce fuel use by trucks accessing these ports by 17%.⁴⁴ In general, however, the GHG and other benefits of freight pricing and management have not been widely studied. Good tools do not exist to analyze these strategies, and their benefits will depend specifically on how they are implemented, making it essential to carefully design programs based on local data collection.

44 – Tioga Group (2008)

45 – Cambridge Systematics, Inc. (2009)

Regional freight distribution centers, inland ports, and logistics parks

Urban consolidation centers, also known as urban ports or dry ports, aim to maximize the efficiency of the trucking industry supply chain by providing truckers with a point at which to transfer goods from larger vehicles designed for intercity movement to smaller vehicles more appropriate for congested urban streets, as well as providing a shared space to wait during peak times and make faster deliveries when road space is liberated. Logistics parks, sometimes known as “freight villages,” cluster distribution and assembly facilities around a rail terminal to minimize the amount of time and truck travel needed to collate goods arriving from global and national suppliers and by train and dispatching loads tailored to the needs of a specific store by truck. There are a number of examples of logistics parks in Europe.

These strategies have received little implementation and there is little evidence of the GHG benefits of such strategies. One study concluded that the benefits of such centers if implemented in the United States would be modest due to limited potential to shift traffic (less than 0.5 MtCO₂e per year).⁴⁵ The benefits of logistics parks also have not been well studied, but may be viewed as a valuable component of a larger intermodal freight system.

Green vehicle energy efficiency and fuel switching

The fuel efficiency of all vehicles can be improved through technologies that are currently available. Since GHG emissions are directly proportional to fossil fuel use, they would decrease with fuel efficiency improvement. Further emission reductions can accrue by replacing gasoline and diesel with less carbon-intensive natural gas in road vehicles, an option that is already commercial in many countries. The benefits of biofuel use are more questionable. Energy efficiency improvement is not limited to road vehicles. There are substantial opportunities for railways, ships, and aviation as well. Some of the options are discussed below.

Efficient cars and motorcycles

The International Energy Agency in 2008 estimated that fuel consumption and GHG emissions from world cars will roughly double between 2000 and 2050. A report by the Global Fuel Economy Initiative,⁴⁶ however, estimates that a global move towards a more efficient fuel economy at a scale already technically achievable, utilizing cost-effective incremental fuel economy technologies for cars, complemented by shifts to low-carbon fuels, could save over six billion barrels of oil per year by 2050, cut close to half of GHG emissions from cars, and generate significant local air pollution benefits.

The technologies required to improve efficiency of new cars in the short- to medium-term involve incremental changes to conventional internal combustion engines

and drive systems along with weight reduction and better aerodynamics. Low-cost immediate technology based improvements to enhance efficiency include better engine tuning, replacing tires and lubricating oils, promoting fuel efficient driving (eco-driving), reducing vehicle weight by removing unnecessary items and drag, and, of particular importance to developing countries, implementing regulation or incentives to promote fuel economy in imported second hand vehicles.

Efficient trucks

Truck fuel cost is the key driver for adopting new technology and the number one expense for heavy truck fleets.⁴⁷ Opportunities for increasing freight efficiency include a) the implementation of logistics technology to minimize empty- or partly-loaded trucks, and b) the consideration of efficiency criteria in the regulations that limit the size, shape, and configuration of long-haul freight trucks. Technological improvements currently under development that are expected to bring higher levels of freight and fuel efficiency for truck systems (truck and trailer) include: the introduction of advanced lightweight materials such as carbon fiber; improvements in engine systems through advance combustion, waste heat recovery and friction and wear reduction; reductions in the aerodynamic drag by achieving trailer gap reductions and tractor trailer integration; accessory load reduction through electrification of accessory loads such as power steering and air conditioning; and drivetrain optimization through friction and wear reduction and hybridization.

46 – Global Fuel Economy Initiative (2009)
47 – US Department of Energy. (2009)

Advanced energy storage (particularly for hybrid and idle reduction systems) is still a challenge for heavy trucks, since truck duty cycles and power requirements are very different from those of light-duty vehicles. However, they are viable alternatives for trucks used for urban freight delivery.

Biofuels

Biofuels such as methanol, biodiesel, and ethanol produce fewer tail pipe pollutants than conventional gasoline and diesel fuel, thus using them would improve local air quality. Vehicles can operate solely on alternative fuels or alternate between conventional fuels and biofuels. It is not clear whether there is a net benefit in terms of GHG emission reductions from the use of current biofuels other than sugar cane ethanol for transportation. This is because indirect emissions associated with land use change and fuel and feedstock production or extraction and distribution might be substantial.

Electric road vehicles

Electric vehicles offer significant savings in terms of fuel and diesel. Furthermore, the introduction of grid-connected battery electric vehicles – including battery operated electric vehicles, plug-in hybrids and possibly hydrogen fuel cell vehicles – will contribute to significant efficiency improvements and to a fuel switch toward electricity. The fuel switch towards electric vehicles will become more viable if further battery improvements are achieved and the technology becomes cost-effective. Gains in terms of GHG emissions reductions from electric vehicles will depend on the ability of countries to generate low carbon electricity in large scale.

Efficient ships

Although ships are the most fuel-efficient mode of transport, international shipping accounted for approximately 2.7% of total world GHG emissions in 2007.⁴⁸ According to the Center for Climate and Energy Solutions, “technological options for more efficient new ships include larger ship sizes, hull and propeller optimization, more efficient engines, and novel low-resistance hull coatings.”

48 – Buhaug, Ø., et. al. (2009)

Part 3

GHG Measurement and Accounting Principles

Introduction to Key Terms and Concepts

This section provides an introduction to the principles and key terms of GHG measurement and accounting and an overview of the main challenges in GHG measurement in the transport sector.

Greenhouse gas (GHG). A GHG is a gas in the atmosphere that can absorb infrared radiation emitted by the earth surface. This process is the fundamental cause of the greenhouse effect. The main GHGs are water vapor (H₂O), carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and ozone (O₃). There are also GHGs that are only produced by human activities, such as chlorofluorocarbons (CFCs), sulphur hexafluoride, hydrofluorocarbons, perfluorocarbons, and nitrogen trifluoride.

GHG emissions. GHGs have both natural and human-caused sources. Since the industrial revolution, human activities have added GHGs to the atmosphere, mainly through the burning of fossil fuels and clearing of forests. The GHG emissions resulting from human activity are called anthropogenic GHG emissions.

Global Warming Potential (GWP). The GWP for a particular GHG is the ratio of heat trapped by one unit mass of the GHG to that of one unit mass of CO₂ over a specified time period.⁴⁹ Typically, GWPs are reported with a 100-year time period.⁵⁰

The main GHGs, their anthropogenic sources and their 100-year GWPs are shown in Table 6.

GHG emissions from transport. GHG emissions from transportation sources include CO₂, CH₄, N₂O, HCFCs, and HFCs. CO₂ is a direct by-product of fossil fuel combustion, whereas CH₄ and N₂O are emitted in vehicle exhaust (CH₄ can also be emitted as leakage from natural

Table 6. Main GHGs, sources, and Global Warming Potentials⁵¹

MAIN GHGS	SOURCES OF GHG EMISSIONS	GWP (100 YEAR TIME HORIZON)
Carbon dioxide (CO ₂)	Burning of fossil fuels and deforestation leading to higher CO ₂ concentrations in the atmosphere. Land use changes primarily caused by deforestation in the tropics account for up to one third of total anthropogenic CO ₂ emissions.	1
Methane (CH ₄)	Livestock enteric fermentation and manure management, rice farming, land use and wetland changes, oil, gas and coal exploration and production, and waste management.	25
Chlorofluorocarbons, hydrochlorofluorocarbons, and hydrofluorocarbons	Use of chlorofluorocarbons (CFCs), hydrochlorofluorocarbons (HCFCs), and hydrofluorocarbons (HFCs) in refrigeration and air conditioning systems, and use of CFCs and halons in the fire suppression and manufacturing processes.	up to 14,800
Nitrous oxide (N ₂ O)	Agricultural activities (including the use of fertilizers), fossil fuel combustion, and the production of adipic and nitric acid.	298

49 – <http://www.epa.gov/highwp1/scientific.html>

50 – The GWP changes depending on the time horizon assessed, but in general the 100-year GWP is used for comparison purposes.

51 – Intergovernmental Panel on Climate Change. Fourth Assessment Report (AR4). (2007)

gas). HCFCs and HFCs are emitted as leakage from air conditioning systems. Transport sources emit other compounds, in addition to GHG emissions, such as O₃, carbon monoxide (CO), and aerosols that are believed to have an indirect effect on global warming. These compounds are not generally included in transportation GHG emissions estimates as their lifetime in the atmosphere varies and scientists have not been able to quantify their impact with certainty.⁵²

CO₂ is by far the most significant GHG emitted by transportation sources and it is generally acceptable to focus primarily on these emissions as an indication of total GHG emissions. Figure 17 describes how to calculate CO₂ emissions from fossil fuel combustion.

GHG emissions inventory. An inventory is a quantification of GHG emissions by source and by gas. Inventories can be reported for entire countries and/or for individual states, cities, industry sectors, companies, or other entities. Since CO₂ is the main emissions source in transport, inventories in this sector are often limited to this gas.

ASIF Framework. As noted above and shown in Figure 17, transport CO₂ emissions depend mainly on fossil fuel consumption. Fuel consumption itself depends on many factors, and transport emissions are often expressed by the so-called ASIF framework, initially proposed by Schipper et al.,⁵³ and shown in Figure 17.

BOX 2: Carbon dioxide emissions from fossil fuel combustion

CO₂ emissions from fossil fuel combustion are obtained by multiplying the quantity of fuel consumed by a number of coefficients as described below:

CO₂ emissions = fuel combusted x fuel carbon content x fraction oxidized x (44/12)

The fuel carbon content is expressed in terms of the type and quantity of fuel consumed, a fuel specific carbon content coefficient, e.g. grams of carbon per liter of gasoline, and an oxidation factor.

When fuel is burned, most of the carbon oxidizes to CO₂ and is emitted to the atmosphere. As a result, the oxidation factor for transportation is in general assumed to be 100%.

To calculate the CO₂ emitted, carbon emissions are multiplied by (44/12) which stands for the ratio of the molecular weights of CO₂ (44) to carbon (12).

To obtain total CO₂ emissions, one applies this equation for each fossil fuel, summing the total.

Thus, the data required to calculate the CO₂ emissions from fossil fuel combustion is limited to fuel consumption in terms of energy units and a set of publicly available default coefficients. For greater levels of accuracy, it is recommended that physical units of metered fuel consumption are used and then multiplied by fuel-specific heat content default values or supplier-provided values.

52 – International Association of Public Transport. (2009)
53 – Schipper, L., Marie-Lilliu, C., and Gorham, R. (2000)

THE ASIF FRAMEWORK FOR DETERMINING TRANSPORTATION GHG EMISSIONS

(figure 17)

$$\text{TRANSPORTATION EMISSIONS } (G) = A \times S \times I \times F$$

Where:

Activity: total vehicle kilometers and/or passenger kilometers

Structure: modal share

Intensity: energy intensity of each mode

Fuel: fuel type and emissions per unit of fuel

According to the ASIF equation, GHG emissions in the transport sector (G) are dependent on four items:

1. transport activity (A);
2. modal structure (S);
3. energy intensity (I); and
4. fuel (F).

Each of these items is discussed below.

Transport Activity (A). This is the total demand for transport, which is normally separated into passenger and freight, and often expressed in passenger-kilometers (PKM) and tonne-km (TKM) respectively. PKM are determined by summing the distance traveled by each person (in terms of km) over the population under study. Similarly, TKM is determined by the movement of one tonne of freight over a distance of one kilometer, and it is calculated by multiplying the vehicle load in tonnes by the distance transported. Increases in population lead to increases in PKM. Increased economic activity generally implies increased TKM.

Modal Structure (S). The modal structure is represented by the share of total travel by each available mode, e.g. automobile, bus, train, taxi, bicycle, airplane, etc. for passenger transport and truck, van, rail, airplane, ship, etc. for freight transport. The choice of transport mode is affected by their availability, the speed and travel time provided by the available modes, the price of fuel and vehicles, income levels, security concerns, and social/psychological dynamics.

Energy Intensity (I). The energy intensity is the energy consumed per unit of travel. For passenger travel it may be defined in terms of energy use per vehicle-km (VKM), or PKM. It depends on vehicle energy efficiency, utilization of vehicle capacity, and “optimality”. Optimality is related to the optimal/most efficient usage of the vehicle as well as the infrastructure where it operates (i.e. poor quality roads or very congested roads decrease vehicle optimality for both passenger and freight transport). For passenger transport, for example, energy intensity is low for a fully loaded bus or train with an efficient engine and high for an old, inefficient, large car with only one occupant. For freight transport, the energy intensity is low for ship and

rail transport, and higher for road transport and aviation. Trips with partial or no loads increase energy intensity by unit of goods or persons transported.

Fuel (F). The fuel type determines its carbon content. So far, we have only mentioned fossil fuels, mainly gasoline and diesel. For these fuels, the carbon content is well defined and generally similar in different countries. It is defined in terms of the emissions factor for the fuel, e.g. in grams of CO₂ per liter (gCO₂/liter), or tonnes of CO₂ per tonne of fuel (tCO₂/t). CO₂ emissions from the combustion of renewable fuels, e.g. ethanol or methyl ester, is often assumed to be zero, since the carbon in the CO₂ emitted during combustion was absorbed from the air when the plant (from which the biofuel was made) grew. However, there are emissions involved in plant growing, and these are captured in a life-cycle assessment (this is described in more detail below). Transport can also be electrically powered, e.g. trains, subways, trams, trolleybuses, and, more recently, plug-in hybrid and electric vehicles. In these cases, the electricity is supplied by the grid. The emission factor (expressed in gCO₂/kWh or tCO₂/MWh) depends on the mix of fuels used to generate and supply electricity to the grid in question. Therefore, the ultimate GHG impact of vehicle electrification will depend on the carbon-intensity of electricity from the grid.

Sustainable transport measures may seek to have an impact on one or more elements of the ASIF framework. Travel demand management measures would affect the activity and structure elements, while advanced vehicle technologies would primarily impact energy intensity and fuel.

Life cycle assessment of transport emissions. The discussion above has considered emissions from fossil fuel combustion. A life cycle assessment – also known as cradle-to-grave analysis – incorporates the emissions associated with all stages of a product life or process. A life-cycle assessment of emissions from transportation takes into account the emissions associated with the energy used for powering vehicles as well as the emissions associated with vehicle manufacturing and maintenance, infrastructure development, fuel extraction and distribution, and other associated activities.

Emissions in a life cycle assessment are usually classified as upstream, downstream, or direct. Upstream emissions are those that occur before a product is used or a process starts and include, for example, the emissions associated with the extraction, processing, and distribution of raw materials, the manufacturing and assembly of parts (as opposed to a final product), and the construction of infrastructure required to use the final product. Downstream emissions are those associated with the disposal and/or recycling of a product or infrastructure material. Direct emissions are those associated with the operation and maintenance of vehicles, infrastructure, etc. Table 7 provides examples of emissions associated with transport life cycle assessments.

Transportation life cycle analysis can be useful for planning at the project level, in cases where a project has a large construction footprint. Construction emissions tend to be larger in proportion to lifetime operational emissions for projects involving substantial tunnel or elevated structures, such as metros or underground or elevated motorways. It should be noted, however, that current methods for infrastructure and vehicle life cycle analysis are generally data-intensive and not well developed.

Table 7. Life cycle of transportation emissions⁵⁴

	VEHICLE CYCLE	FUEL CYCLE	INFRASTRUCTURE CYCLE
Upstream emissions	Extraction, processing, manufacturing, assembling, and distribution of the raw materials used to manufacture a vehicle or parts of a vehicle.	Fuel upstream emissions are also called well-to-pump emissions. These emissions derive from the exploration, drilling, refining/processing, storage, and distribution of fuel types. Care should be taken to consider fugitive emissions. In the case of biomass or biofuels, land-use changes, as well as agricultural activities including transport and distribution, should be accounted as well.	Clearing of land, production of construction raw materials, and construction activities.
Direct emissions	Energy consumption from vehicle maintenance activities and tire wear.	Fuel combustion.	Re-surfacing, maintenance, and cleaning.
Downstream emissions	Disposal and recycling of parts, tires and vehicles.	Disposal and recycling of oil products.	Disposal and recycling of infrastructure material.

Biofuels comprise another area where life cycle analysis is important in determining overall emissions. The fuel cycle emissions of biofuels show much greater variability (when compared with direct emissions) than those of fossil fuels, depending upon production pathways and assumptions regarding indirect impacts (such as land conversion required for growing feedstock). For example, ethanol obtained from sugar cane usually results in lower life cycle GHG emissions than ethanol obtained from corn. Moreover, policy decisions on biofuel production and use depend on agriculture and land-use considerations, rather than transport policy.

Two models are commonly used in the United States for transportation life cycle analysis: the Lifecycle Emissions Model (LEM)⁵⁵ and the Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation model (GREET).⁵⁶ Both models account for upstream fuel cycle and vehicle cycle emissions for a variety of fuel and vehicle categories. However, both involve substantial data requirements and assumptions.

Project. The term “project” is used in a broad sense, to mean the set of activities or interventions proposed or under consideration for climate change mitigation. This may be a single physical project (such as a road improvement or mass transit line), a program comprising many projects, or non-physical actions such as policy changes (e.g. fuel pricing, fuel efficiency standards, land use).

Project boundary. The project boundary defines the geographic or physical boundary within which emissions reductions are to be determined.

Project lifetime. The project lifetime is the expected duration of the proposed mitigation action. It should be noted that this duration is different from, and usually larger than, the “crediting period”⁵⁷ as applied to projects in carbon markets.

54 – US Environmental Protection Agency. (2006)

55 – Delucchi, M. (2003)

56 – US Department of Energy, Center for Transportation Research (2001)

57 – In the context of the CDM, crediting period is the period for which emission reductions from the baseline are verified and certified by independent auditors in order to issue certified emission reductions (CERs).

Measurement (Monitoring), Reporting, and Verification (or Measurable, Reportable, Verifiable, MRV).

MRV is a term that is used to describe requirements or procedures for measuring, reporting, and verifying (in some cases via third-party review) that the emission reductions promised by a project have actually been achieved. An MRV approach should be able to answer the following questions:⁵⁸

- » Are actions really happening?
- » Are the resources used for the purpose they were provided for?
- » How effectively are actions being implemented?
- » How large is the emissions and emission reductions impact?

Ex-Ante vs. Ex-Post Evaluation. Ex-ante evaluation is an estimate of the impacts of a project before it is implemented. Ex-ante estimates use available data and forecasting methods to determine the likely impacts of the project. An ex-post evaluation is an estimate (or measurement) of the impacts of a project after it has been implemented, using to the extent possible observed data on the project's actual impacts.

Other GHGs. In the discussion so far, we have focused exclusively on CO₂ from fossil fuel combustion, be that in the vehicle itself or at power plants connected to the grid supplying electricity to a transport system. Small amounts of CH₄ and N₂O are also emitted in natural gas combustion. These can be included in the basic concept described in the ASIF Framework (Figure 17). Where natural gas is the fuel, there are CH₄ upstream emissions from gas production, transportation, treatment, and supply activities. It should be recalled that the dominant GHG emission source in transport remains CO₂ from fossil fuel combustion. Therefore, to a first approximation, ignoring emissions from other GHGs will not lead to a significant error in estimating emission reductions from a mitigation project.

58 – Sterk, W. (2011).

Challenges in Measuring Emission Reductions from Transport Projects

In order to achieve ambitious transport GHG emission reduction objectives, policymakers need to collect comprehensive and timely data addressing: fleet composition, fleet characteristics, transport activity, mode share, fuel consumption, and emission rates for each transport mode. Investing in a robust data collection and monitoring framework to guide sustainable transportation strategies saves money in the long run, as it helps avoid misdirected GHG reduction policies.

There are a number of challenges associated with collecting the data required for both ex-ante forecasting and ex-post measurement of the GHG impacts of transport policies. Some of these challenges include: ⁵⁹

- » Rapid growth or technological change which makes it difficult to accurately estimate or forecast what a BAU scenario would be in terms of GHG emissions;
- » Factors that change while a project is being implemented and affect transport decisions, e.g. income growth, fuel prices;
- » Impacts that are indirect or occur with a considerable time lag such as land use policies or roadway investment affecting development; and
- » Feedback or unintended effects such as vehicle efficiency measures that increase the demand for transport by making travel cheaper.

Furthermore, in ex-ante evaluation of transport projects, there is often considerable uncertainty regarding what the actual impact of measures that lead to GHG reductions will be (e.g. how many people would eventually decide to switch from cars or motorcycles to a mass transit system). In the case of ex-post evaluation, it is impossible to directly observe what would have happened in the absence of the transport project and it is difficult to differentiate between changes in emissions triggered by the project and changes triggered by other factors.

Transport sector interventions, particularly those affecting transport demand,⁶⁰ are most effective when comprising a combination of emission reduction measures because of the synergies that exist between them. For example, compact land use patterns provide a market for public transport, which BRT or rail investments can then serve. The implementation of pricing policies designed to make it more expensive to go into CBD or congested areas will most likely lead to greater GHG emissions reductions and encounter less opposition from users if alternatives to private vehicle travel are made available before the policies are introduced. Furthermore, it has been proven in a number of OECD countries that coordinating the deployment of a large range of mobility options covering traditional public transport, BRT, car-sharing schemes, bike sharing systems, etc. enhances the likelihood that

59 – Sterk, W. (2011)

60 – Based on Ellis, J., and S. Moarif (2009)

passengers will transition towards less GHG intensive travel in urban areas. Comprehensive low-carbon transport plans are a way of moving beyond a project-by-project approach to GHG mitigation and have been suggested as a centerpiece for emerging climate change mitigation financing schemes, e.g. NAMAs.⁶¹

A sustainable transportation system aims at meeting basic mobility needs in a safely, affordable, equitable, effective, and efficient manner that would support the needs of a growing economy while reducing

environmental and social impacts. A shortcoming of the more rigorous methodologies available today to evaluate the sustainability impact of transport interventions derives from the fact that these interventions require measures implemented to be evaluated in isolation, thereby failing to capture the full effect that measures might have over time on other modes of transport. To address this shortcoming and assist in overall MRV efforts, policymakers should consider implementing a transport sector GHG emissions inventory as part of their transport sector GHG emission reduction strategy.

61 – Center for Clean Air Policy. (2010)

Part 4

Tools and Methodologies

to Determine GHG Emission Reductions from
Mitigation Activities



Quantifying GHG Emissions from Transport Mitigation Strategies

A number of tools and methodologies have been developed in recent years to determine GHG emissions reductions in transport projects, mostly in relation to carbon finance. Two of the main sources for these tools are the methodologies developed for CDM projects and the emissions models used in connection with projects implemented under the GEF, which are known as Transport Emissions Evaluation Models for Projects (TEEMP). This chapter considers those tools and methodologies that are most useful for the purpose of determining GHG emissions reductions from mitigation activities in transport. They are reviewed as general procedures, without reference to their suitability for any specific financing mechanism. The reasons are as follows:

- » New climate change mitigation financing schemes are emerging and MRV requirements are yet to be defined for these schemes;
- » Tools need not be tied to climate finance since determining the GHG emissions impact should be part of the evaluation of transport activities, including cases such as:
 - A country, province, or city may undertake transport projects without reference to any climate finance scheme; and
 - Transport projects may be financed without being linked to climate finance.

Part II of this report (Overview of Transportation GHG Mitigation Strategies) includes eleven categories of mitigation strategies. The left column of Table 8 lists these strategies (I to XI), together with subcategories. Since the TEEMP tools and CDM methodologies are specific to project types, the table indicates which TEEMP models and CDM methodologies are applicable for those categories or sub-categories where these exist.

Following the table we review a number of CDM methodologies, followed by a few TEEMP tools. The overall impact of a set of mitigation actions, e.g. comprising a sustainable urban mobility plan or a national freight transport plan, is best determined through GHG inventories, which are reviewed at the end of Part IV.

Mitigation options listed in Table 8 cover urban and inter-urban transport, passenger as well as freight transport.

TEEMP models and CDM methodologies are all based on the ASIF framework presented in Parts II and III of the report, i.e. emissions depend on level of activity (A), structure (S), intensity (I) and fuel (F). The simplest transport tool or methodology would correspond to a situation where only Intensity (I) is affected by the mitigation activity. Intensity improvements would reflect the introduction of a more efficient vehicle to replace

an existing vehicle, or the retrofitting of an existing vehicle to make it more fuel efficient. There are two CDM methodologies, AMS-III.AA and AMS-III.AP, which

capture the retrofitting of an existing vehicle to make it more fuel-efficient. These and other CDM methodologies are discussed below.

Table 8. Models and methodologies for quantifying GHG emissions reduction for different transport mitigation strategies

PUBLIC TRANSPORTATION IMPROVEMENTS		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Public transport operational improvements		
2. Transit fare system improvements		
3. Public transportation system integration in priority corridors		
4. Bus rapid transit	BRT Projects	AM0031, ACM0016
5. Light rail, metro rail, and commuter rail systems	LRT/MRT Projects Railway Projects	ACM0016
6. Bus useful life regulation and vehicle phase-out, and vehicle scrappage programs		
7. Cable cars for mass rapid transit systems		AMS-III.U
NON-MOTORIZED TRANSPORTATION POLICIES		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. New and improved sidewalks and pedestrian crossings	Pedestrian Projects	
2. Traffic calming		
3. Improved bicycle infrastructure, networks, and supporting facilities	Bike Sharing Bikeways	
PRICING MOTOR VEHICLE USE		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Motor fuel taxes and subsidies		
2. Road pricing		
3. Congestion pricing		
4. Cordon pricing		
LAND USE STRATEGIES		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Urban planning codes and practices		
2. Transit oriented development		
3. Car-free zones and restricted traffic streets		
PARKING PRICING AND MANAGEMENT		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Parking pricing	Pricing	
2. Managing on-street parking supply	Pricing	
3. Establishing maximum or reducing minimum parking requirements		

COMMUTER TRAVEL REDUCTION POLICIES		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Flexible time schedules		
2. Compressed work weeks and telework	Commuter Strategies	
3. Ride-share matching and incentives	Commuter Strategies	
4. Tax incentives for alternative mode use and disincentives for employer provided free parking	Commuter Strategies	
MOTOR VEHICLE ACCESS AND USE		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Car-sharing		
2. Motor vehicle registration fees and taxes		
3. Motor vehicle quota systems		
4. License plate restrictions		
SYSTEM OPERATIONS AND MANAGEMENT		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Reduce national speed limits on motorways		
2. Eco-driving and vehicle maintenance programs	Eco-Driving	
3. Intelligent transportation systems		
ROADWAY CAPACITY EXPANSION OR REDUCTION		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Roadway capacity expansion/reduction	Expressway	
MULTIMODAL FREIGHT STRATEGIES		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Enhancement of intermodal freight infrastructure		AM0090
2. Freight pricing and management		
3. Regional freight distribution centers, inland ports, and logistics parks		
VEHICLE ENERGY EFFICIENCY AND FUEL SWITCHING		
TRANSPORT MITIGATION STRATEGY	TEEMP MODELS	CDM METHODOLOGY
1. Electric and hybrid vehicles		AMS.III.C
2. Useful life regulation and vehicle phase-out, and vehicle scrappage programs		
3. Retrofit technologies		AMS-III.AA
4. Energy efficiency activities using post-fit idling stop device		AMS-III.AP
5. Installing digital tachograph systems		AMS-III.AT
6. Low-emission vehicles/technologies to commercial vehicle fleets		AMS.III.S
7. Introduction of bio-CNG		AMS-III.AQ
8. LNG buses		AMS-III.AY

CDM Methodologies

The CDM of the Kyoto Protocol⁶² has produced a number of methodologies to estimate and monitor GHG emissions reductions from projects claiming carbon credits.

The baseline scenario for a CDM project activity is defined as the scenario “that reasonably represents the anthropogenic emissions by sources of GHG that would occur in the absence of the proposed CDM project activity.” Baseline emissions are GHG emissions that would occur in the baseline scenario. Similarly, the project scenario corresponds to the scenario with the project activity, and the corresponding GHG emissions are called the project emissions.

An important concept which defines the eligibility of a project in the CDM is additionality. Additionality means that a given project activity would not have happened without the financial flows generated by the CDM and that the reductions in emissions generated are additional to any that would have occurred in the absence of the registered project activity.⁶³ The concept is important, since carbon credits from emissions reductions generated by a CDM project can be acquired by Annex I⁶⁴ countries that ratified the Kyoto Protocol, to compensate (or offset) their own GHG emissions by the same amount. Consider the case where some emissions reductions in a non-Annex I country would have happened anyway and Annex I countries were to claim these non-additional emissions reductions. Under this scenario, the Annex I countries would not be required to reduce their emissions domestically by this amount, but they could still meet their commitments under the Kyoto Protocol. The result would be that total GHG emissions by countries

that accepted GHG limitation targets would increase because of including such non-additional carbon credits. Because of the importance of additionality as proof of genuine emissions reductions, in the context of the Kyoto Protocol, there are stringent rules for the determination of additionality. Unfortunately, for certain project categories, additionality can be controversial, or it may be difficult to determine in an absolute manner.

Carbon credits generated under the Kyoto Protocol imply transference of funds from Annex I countries to non-Annex I countries where CDM projects are developed. If this transference were not linked to allowing Annex I countries to offset their emissions, the concept of additionality would be less critical. In the GEF framework, the transference of funds to one country does not allow another country to increase its emissions. The GEF includes a concept of “incremental costs,” which are additional costs associated with transforming a project with national benefits into one with global environmental benefits. GEF grants are intended to cover some of the cost difference or “incremental costs.”

CDM methodologies generally comprise two main parts: baseline setting and monitoring plan. The initial function of each methodology is to establish the appropriate baseline scenario and determine if the proposed project activity is additional. If additional, the methodology specifies how to determine GHG emissions reductions, usually based on a monitoring procedure, specified within the methodology.

62 – CDM background is provided in Part I, Section B of this Report.

63 – Kyoto Protocol, Article 12(5) and CDM Rulebook <http://cdmrulebook.org>

64 – Annex I Parties to the UNFCCC include all original OECD member countries and countries with economies in transition. Thus, Non-Annex I Parties are developing country Parties. Under both UNFCCC and the Kyoto Protocol, Annex I Parties have more stringent requirements regarding limits to GHG emissions and obligation to provide financial and technical resources to meet the overall objectives of the Convention and Protocol.

In the following sections we shall be reviewing some of the most commonly applied transport methodologies, starting with the simplest and then moving to increasingly complex ones as detailed below:

- » The simplest CDM methodologies, applicable to vehicle retrofits without fuel shifting, are AMS-III.AA and AMS-III.AP, since, as mentioned above, they only involve the “I” term of the ASIF framework.⁶⁵ These two methodologies are similar in complexity, the first referring to engine modifications while the second refers to a device that stops the engine when idling. Because of the similarity of these two, we choose to focus on CDM methodology AMS-III.AA.
- » Somewhat more complex mitigation activities involve fuel savings and fuel shifting, so that both the Intensity (I) and the Fuel (F) terms of the ASIF framework are involved. There are two CDM methodologies in this category: AMS-III.S, which involves the introduction of low-emission vehicles/ technologies to commercial vehicle fleets, and AMS-III.C, that determines emissions reductions by electric and hybrid vehicles. While they have different scopes, they are similar in complexity, so we choose to examine only AMS-III.S.
- » Finally there are more complex mitigation activities involving mode shifting, e.g. passengers travelling by bus or bicycle instead of driving a car, or taking a train instead of a bus. These activities change the transport Activity (A) and modal Structure (S), and often the “I” and “F” terms of the ASIF framework as well. In consequence, these methodologies are more complicated and require substantially more data. The simplest CDM methodology in this

category is AMS-III.U: Cable Cars for Mass Rapid Transit System, which we review first. Subsequently, we review “AM0031: Bus rapid transit projects,” which is substantially more complex.

- » Each CDM methodology is valid for a set of applicability conditions. Some methodologies are very restrictive in their applicability, while others are more widely applicable, called consolidated methodologies, and designated “ACM.” They generally build on (consolidate) several previous methodologies. The last CDM methodology we present is the most complex but at the same time the one with broadest applicability for mass rapid transit project activities “ACM0016: Mass Rapid Transit Projects.”

The general formula for determining emission reductions is as shown in figure 18:⁶⁶

Baseline and project emissions correspond to emissions in the baseline and project scenarios, as defined earlier. CDM defines leakage emissions as “the net change of anthropogenic emissions by sources of GHG which occurs outside the project boundary, and which is measurable and attributable to the CDM project activity.”⁶⁷

CDM methodologies are often complicated, and when a great deal of data is required, the monitoring requirements can be very expensive. Following our review of CDM methodologies we review other alternatives, specifically TEEMP tools and emissions inventories, which tend to be simpler and/or offer other advantages.

65 – The CDM designation “AMS” refers to small-scale methodologies, which tend to be simpler and require less data than “normal” methodologies, which are designated “AM”.

66 – This equation can be found in most, if not all, CDM methodologies

67 – CDM Glossary of Terms. Version 6. 2012



DETERMINING EMISSION REDUCTIONS IN THE CDM

(figure 18)

$$ER_y = BE_y - PE_y - LE_y$$

Where:

ER_y : Emission reductions in year y ($t\ CO_2e$)

BE_y : Baseline emissions in year y ($t\ CO_2e$)

PE_y : Project emissions in year y ($t\ CO_2e$)

LE_y : Leakage emissions in year y ($t\ CO_2e$)

AMS-III.AA. transportation energy efficiency activities using retrofit technologies

Methodology AMS-III.AA applies to existing or used commercial passenger vehicles that undergo an engine retrofit, which results in higher fuel efficiency levels.

Applicability. This methodology is applicable under the conditions shown in Box 3.

Project boundary. Each CDM methodology defines a project boundary, within which all GHG emissions need to be considered. This methodology specifies the project boundary as the physical, geographical location of the retrofit vehicles that are part of the project activity being implemented. The physical or geographical boundary can be a city (in the case of vehicles used on urban routes) or routes between cities (for vehicles used in peri-urban routes).⁶⁸

GHGs included. Only CO_2 .

Baseline emissions. Since only improvements in terms of energy efficiency are considered (i.e. “I” of ASIF), baseline emissions are determined in terms of a baseline emissions factor (BEF). The BEF is determined by fuel consumption and its respective fuel emission factor, expressed as tonnes of CO_2 per km. Baseline emissions in a given year are determined by the product of the number of vehicles (N), the average distance traveled per year (AD), and the BEF. Note that the values for both N and AD are determined for the project vehicles, i.e. after the engine modification. Thus, baseline emissions correspond to what baseline vehicles would have emitted if they existed in the same number as project vehicles and traveled the same average distance per year. This

corresponds to a so-called dynamic-baseline scenario where baseline emissions depend on parameters determined under the project scenario. In terms of the “ASIF” framework, we are considering that the activity level (“A” of ASIF), defined by N and AD, is unchanged from baseline to project scenarios.

Project emissions. Project emissions are determined in the same way as baseline emissions, noting that N and AD are the same in each case, and only fuel consumption is different for the project activity.

Leakage. The methodology does not require any considerations of leakage emissions.

Box 3: Applicability conditions for AMS-III.AA

It is applicable for:

- » Engine retrofit of existing commercial passenger vehicles e.g., buses, motorized rickshaws, taxis
- » Vehicles that operate in comparable routes and traffic situations under the baseline and project scenarios

It is not applicable for:

- » Introduction of brand new vehicles or low-emission vehicles
- » Fuel switch in existing vehicles
- » Freight transport
- » Modal shift in transportation
- » Private vehicles

AMS-III.S. Introduction of low-emission vehicles/technologies to commercial vehicle fleets

While AMS-III.AA considered energy efficiency without fuel shifting, thus affecting only the “I” of ASIF, AMS-III.S includes fuel shifting, so that the “F” of “ASIF” may also change from the baseline to the project scenario. In this case, the project scenario may include fuel as well as electric commercial vehicles; thus “fuel” is

interpreted to also include electricity. Moreover, this methodology applies to both commercial passenger and freight vehicles.

Applicability. This methodology is applicable under the conditions shown in Box 4.



Project boundary. The project boundary includes (a) the fleet to which low emission vehicles are introduced; (b) the geographical area covering the physical routes of the fleet; and (c) auxiliary facilities such as fuelling stations, workshops and service stations visited by the vehicles in the fleet.

GHGs included. Mainly CO₂; however, the methodology requires that leakage of HFC be accounted for in situations where “the project vehicles have air conditioning whereas the baseline vehicles do not.” If data are not available to account for leakage, a default value shall be used.

Baseline emissions. The procedure is similar to AMS-III.AA, whereas the activity level “A” for the baseline is determined by the number of passengers or freight tonnes multiplied by the distance. However, this methodology allows for the case where the baseline vehicle type is different from the project vehicle, and indicates a procedure for estimating fuel consumption for the baseline vehicle type.

Project emissions. The procedure is very similar to that in AMS-III.AA, i.e., based on fuel consumption and emission factor, and equally straightforward. However, since this methodology allows for electric vehicles, electricity use may need to be taken into account, besides fuel consumption. For fossil fuels the emission factor is determined simply by the carbon content of the fuel. Since electricity for the vehicle is supplied from an interconnected power system fed by many power plants, the process for determining the emission factor associated with the electricity supply is more complicated. To this end, AMS-III.S cites a CDM “methodological tool” for determining emissions from electricity consumption.⁷⁰

The tool for determining emissions from electricity consumption is straightforward, basically involving a multiplication of electricity consumption by the emissions factor of the electric power system, taking into account transmission and distribution losses.

Box 4: Applicability conditions for AMS-III.S⁶⁹

It is applicable for:

- » Introduction of low GHG emitting vehicles
- » Passenger and freight transport
- » New and retrofit vehicles
- » Existing vehicles switching from high GHG intensive to low GHG intensive fossil fuel
- » Vehicles operating on identifiable fixed routes and comparable level of service (average/total number of passengers or tonnage transported and the average distance transported do not change before and after project implementation)

It is not applicable for:

- » Measures that cause a modal shift, e.g. from road to rail
- » Situations where there is a change in the level of service and/or tariffs charged that may lead to changes in patterns of vehicle use

69 – AMS-III.S., version 3

70 – Tool to calculate baseline, project and/or leakage emissions from electricity consumption. http://cdm.unfccc.int/Reference/tools/ls/meth_tool05_v1.pdf

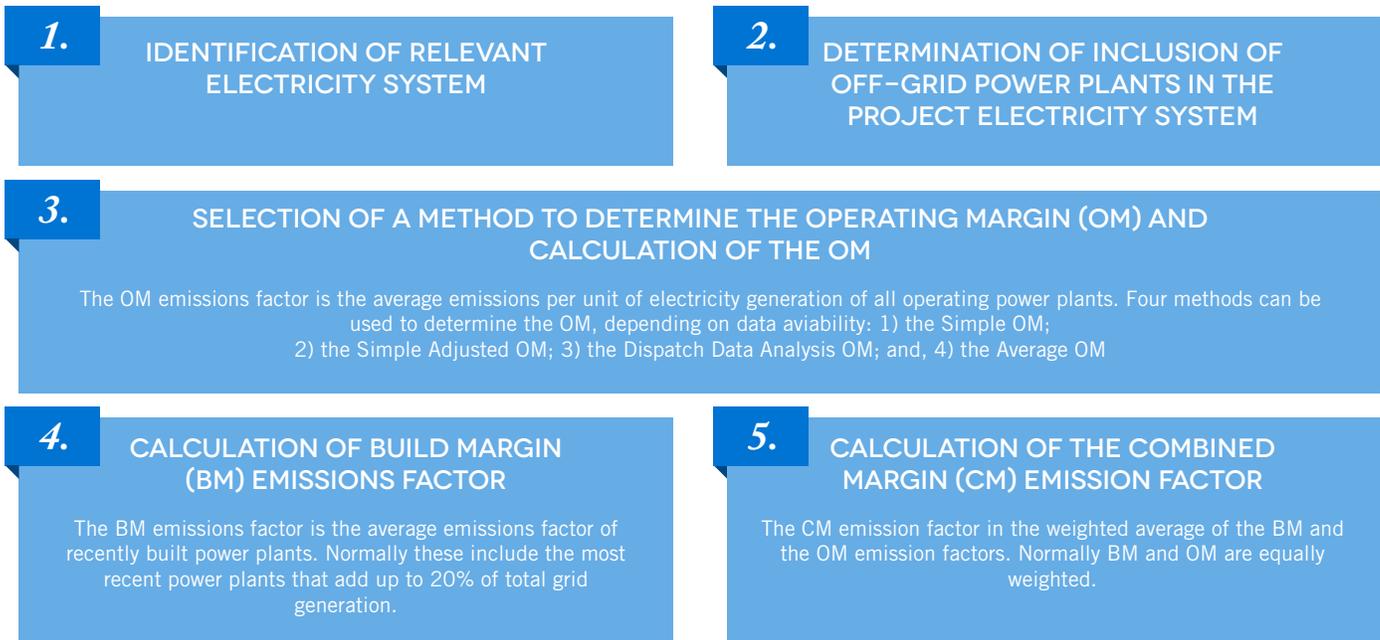
The emissions factor for an electric power system is determined by another tool,⁷¹ which is relatively complex and is described in Figure 19. Since a very large number of CDM projects involve the application of the tool to calculate the emission factor for an electricity system, some national governments calculate the electricity

system emission factor using this tool and make the data publicly available.⁷²

Leakage. The methodology does not require any considerations of leakage emissions.

SIMPLIFIED SCHEMATIC STEPS TO CALCULATE THE EMISSIONS FACTOR FOR AN ELECTRICITY SYSTEM

(figure 19)



71 – Tool to calculate the emission factor for an electricity system. <http://cdm.unfccc.int/methodologies/PAMethodologies/tools/am-tool-07-v2.pdf>

72 – IGES 2012



AMS-U. Cable cars for mass rapid transit system (MRTS)

This is also a small-scale methodology, but inherently more complex than those considered so far⁷³ since all four factors of “ASIF” come into play. It is applicable to situations where a cable car system replaces traditional road-based urban passenger transport. Thus, this is the first methodology we analyze that incorporates changes to parameter “S” of ASIF, i.e., a mode shift from traditional road-based mass transit to a cable car system. Surveys are therefore needed to gather data to determine mode shift. In addition to a mode shift, substituting traditional road-mass transit for a less GHG-intensive cable car system brings about gains in energy efficiency, affecting parameter “I”; and lower fuel consumption due to a fuel switch to electricity, affecting parameter “F”. While most passengers taking the cable car would have used a road vehicle in its absence, from the same origin to the same destination, the methodology allows for so-called “induced traffic,” where new passengers use the cable car who did not switch from a road-based system, e.g. those who previously walked up and down the slope, and tourists, who would not otherwise be taking the cable car at all. Thus, the methodology allows for transport activity “A” to change.

This methodology also introduces the concept of indirect project emissions. Since cable cars operate on fixed routes, passengers may need to take other modes of transport to get to and from the cable car system, thus generating additional GHG emissions that have to be accounted for. The process is illustrated in Figure 22.

Applicability. This methodology is applicable to cable cars substituting traditional road based transport trips, under the conditions shown in Box 5.

Project boundary. The project boundary is the urban geographical area of trips of passengers using the cable car system.

GHGs included. CO₂ emissions from liquid fuels are considered for the calculation of project and baseline emissions, while for gaseous fuels, emissions of CH₄ are included in addition to those of CO₂. N₂O emissions are excluded.

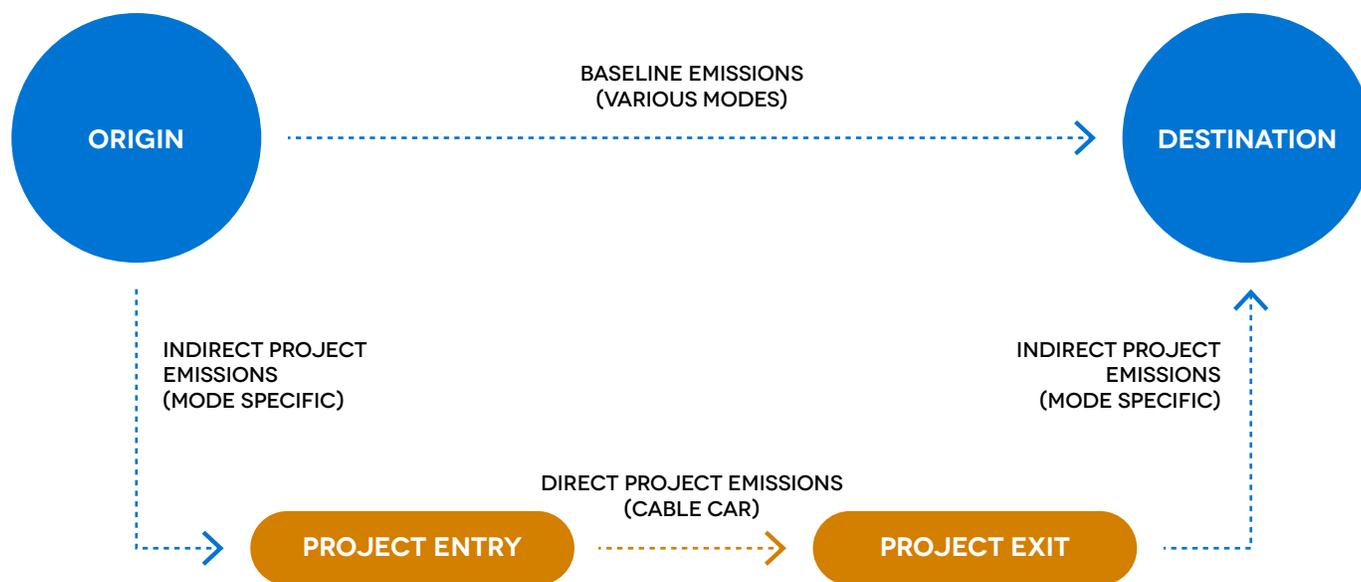
Baseline emissions. The installation of a new cable car system inevitably involves a modal shift. Passengers taking the new cable car system used other transport systems previously. Baseline emissions require a determination of a) what transport systems these passengers would have used in the absence of the cable car, and b) how many shifted from each of the other systems to the cable car. Therefore:

- » Origin-Destination Surveys are required to determine modal shift; the methodology includes an Annex explaining survey principles and a sample survey questionnaire; and
- » Emissions from all involved baseline vehicles must be taken into consideration. The methodology offers default values for certain vehicle categories.

73 – As one indicator of complexity, we note that this methodology is 25 pages long, while the earlier ones were only 6 and 8 pages, respectively.

INDIRECT PROJECT EMISSIONS FROM PASSENGERS USING A CABLE CAR SYSTEM

(figure 20)



SOURCE: AMS-III.U, VER.1, GRAPH 1

Project emissions. Project emissions must account for direct emissions resulting from passengers transported using the cable cars, and indirect emissions as illustrated in Figure 20. The emissions resulting from passengers transported by the cable car system are determined from measured electricity consumption and an emissions factor for electricity generation, taking into account transmission and distribution losses. Indirect project emissions are determined from a survey of passengers taking the cable car system, to determine the modes used to and from the system, and the indirect trip distance per mode and per passenger. The procedure for calculating the indirect emissions is the same as that for determining (direct) project emissions as in methodology AMS-III.S.

Leakage. This methodology requires the consideration of leakage emissions if occupancy rates per vehicle type on average are expected to change by more than 10%. The methodology only requires the inclusion of leakage if the net result of occupancy change is to increase emission reductions, i.e. carbon credits to be obtained.



Box 5: AMS-III.U. Cable cars for MRTS

It is applicable for:

- » A new cable car system
- » Passenger transport only
- » Cable cars as means of mass transit
- » Origin and destination of cable car must be accessible by road
- » Fuel types allowed in baseline and project activity include: electricity, gaseous or liquid fossil fuels

It is not applicable for:

- » Extensions of existing cable car systems
- » Freight transport

AM0031. Bus rapid transit projects⁷⁴

This methodology would apply to situations where a new BRT system is constructed to transport urban passengers, or an existing system is expanded. One advantage of BRT systems is increasing commercial speeds for public transit so that people are likely to shift from private to public transport. Moreover, articulated and double articulated buses have larger carrying capacity⁷⁵ than normal buses so that fuel consumption per PKM is lower. In terms of the ASIF framework, the main benefit of BRTs is in the Intensity (I) term. Activity level (A) of private transport decreases, while that of the BRT buses increases. Thus there is a modal Shift (S) as well. The methodology considers all transport modes for baseline and project scenarios, so in principle the Fuel (F) parameter is also affected. However, since BRT buses are typically diesel fueled, as are conventional buses, the “F” parameter is usually unaffected by this project type.

AM0031 is applicable to cases where the BRT includes both trunk and feeder routes and the entire trip is completed within the system. Therefore all GHG emissions are direct and, unlike AMS-III.U, indirect emissions do not need to be considered. However, AM0031 is a large scale methodology, and adds a number of procedural complexities compared to the small-scale methodologies reviewed above. The main complications arise in the requirement to consider many types of leakage emissions. The BRT may reduce the load factor of other transport modes, increasing their emissions per PKM. The BRT may, additionally, reduce road congestion, encouraging additional traffic. In case there is an increase in gaseous fuels demand in the project scenario, methane emissions from upstream leakage (these derive from the production and transmission/distribution of natural gas) should be included.

74 – AM0031 Version 5

75 – Normal buses usually 10 meters in length have a carrying capacity of less than 100 passengers while articulated and bi-articulated buses 18 meters, and 24 meters in length have a maximum carrying capacity of 160 and 240 passengers respectively.

Applicability. The applicability conditions are summarized in Box 6.

Project boundary. The boundary is defined by the geographical area covered by the BRT system within the city where the project is carried out.

GHGs included. Mainly CO₂, while methane needs to be considered only for gaseous fuels. However, methane emissions may be neglected if used in both the baseline and project scenarios. This is because fuel consumption decreases from baseline to project, so that methane emissions would also decrease. Therefore neglecting them is conservative from a CDM perspective, where conservative assumptions that reduce the estimate of GHG emissions reduction are often allowed.

Baseline emissions. Baseline emissions are estimated both ex-ante i.e., before project implementation, as well as ex-post, in each case using the sequence of steps shown in Table 9.

Since buses in general and BRTs in particular emit less per PKM, i.e. lower gCO₂/PKM, a shift from other vehicles to BRT would reduce emissions. Origin-destination surveys are needed to determine the magnitude of the shift from other transport modes to BRTs. However, if the CDM project proponent does not intend to claim emission reductions from the modal shift, surveys to determine modal shifts are not needed. In this case, it would be assumed that BRT passengers have taken conventional buses in the baseline scenario. In any case, a detailed survey design procedure is provided in Appendix E of the methodology, and a survey questionnaire in Appendix F.

Project emissions. The project emissions comprise emissions from trips undertaken in the new – or extended – BRT system, including both trunk routes and feeder lines. The methodology suggests two options for determining fuel consumption of the buses in the BRT system; the choice depends on data availability. The options are (a) the use of actual fuel consumption data or (b) the use of specific fuel consumption and distance-traveled data.

Box 6: AM0031 – Bus rapid transit projects

It is applicable under the following conditions:

- » Construction and operation of a new BRT system
- » Extension of an existing BRT system
- » Baseline and project scenarios can include all type of fuels and electricity, with some restrictions for biofuels:
 - Project buses must use the same biofuel blend as commonly used by urban buses in the country
 - Project buses shall not use a significantly higher biofuel blend than cars and taxis

- » Only emissions caused by the BRT system are considered i.e., the emissions generated from passenger trips required to connect to and from the BRT system are excluded

It is not applicable under the following situations:

- » Project activity BRT replaces a rail-based MRTS
- » Water based transport systems and freight cannot be included in the baseline



Table 9: Steps for the determination of baseline emissions

STEP	DESCRIPTION	COMMENTS
1	Determine vehicle categories	Generally include buses, cars, taxis, and motorcycles. NMT and “induced traffic” always need to be included. If carbon credits for modal shift from cars, taxis, and motorcycles are not claimed, these categories need not be considered.
2	Determine emissions per kilometer for each category	This is similar to the procedure used in the methodologies AMS-III.AA and AMS-III.S. However, methane emissions from fuel combustion may be included.
3	Determine emissions per passenger for each category	This is based on the emission factor per km (determined above), vehicle occupancy and distance traveled.
4	Technology improvement factor	This factor takes into account future efficiency improvements, e.g. replacement of vehicles by new, more efficient ones. Appendix A of methodology indicates that the fixed, annual, improvement factor is 0.99 for buses, cars, taxis and 0.997 for motorcycles.
5	Change of baseline parameters during project operation	This step is necessary where modal shift is involved, i.e. when passengers shift from vehicles other than buses to the BRT. It takes into account: the load factor or number of passengers per vehicle, the distance traveled, and changes in fuel (for passenger vehicles). In each case, the parameters refer to the vehicle that passengers would have used to travel in the absence of the BRT.
6	Baseline emissions	Determined as the product of emissions factor and passengers, summed for all vehicle categories.

Leakage. The methodology requires detailed consideration of three types of leakage emissions, i.e. increased emissions elsewhere because of the implementation of the project activity:

- 1. Change in load factor in other transport modes.** The use of BRTs may reduce the number of passengers in other transport modes, increasing their fuel intensity. The methodology requires leakage emissions to be taken into account if load factor changes by more than 10%. The methodology includes three appendices indicating procedures for determining load factor for different types of vehicles.
- 2. Reduced congestion.** If a BRT is based on reserving lanes on an existing road, there will be less room for other vehicles and congestion would not be reduced. However, if the BRT is based on new

road infrastructure, more space would be available on the other roads, inducing increased traffic and emissions. The methodology indicates procedures for determining changes in road capacity, and consequent leakage emissions, which need to be considered if positive. The methodology also indicates procedures for determining emissions from increased use of vehicles (as a result of the project, and not from general traffic growth), as well as increase in vehicle speed, in each case only for passenger cars and taxis.

- 3. Upstream emissions associated with the use of gaseous fuels.** Natural gas extraction, transport and distribution releases methane into the atmosphere. In the case of liquefied natural gas, there are emissions associated with fuels and electricity used in liquefying natural gas. These are called “upstream” emissions.

ACM0016. Mass rapid transit projects

While AM0031 is only applicable to BRT systems, ACM0016 is applicable to rail- or bus-based MRTS in urban or suburban regions. ACM0016 is also applicable to BRT systems, however, there is a fundamental difference in approach. AM0031 requires the BRT to include trunk routes and all feeder routes to be within the project activity. Thus, there is no consideration of indirect emissions for passengers to go to and from the BRT (indirect emissions were explained in Figure 22 in the context of cable cars). ACM0016 is applicable to rail based systems, which operate on fixed routes covering limited areas, so that other modes of transport are often needed to reach the system. By the same argument, ACM0016 is applicable to isolated BRT corridors, which do not include feeder routes.

Applicability. The applicability conditions are summarized in Box 7.

Project boundary. The project boundary encompasses the larger urban zone of the city such that it covers trips on the new project MRTS as well as baseline trips from origin to final destination.

GHGs included. Mainly CO₂ and in the case gaseous fuels are consumed, CH₄ should also be included.

Baseline emissions. Baseline emissions are defined as in the previous methodologies reviewed (AMS-III.U and AM0031): these are the emissions associated with the transport modes passengers would have taken in the absence of the project MRTS.

Figure 21 details the essential steps required to determine baseline emissions. The principal inputs are:

- » An Origin-Destination Survey of passengers using the project transport system, to determine what transport mode they would have used in the absence of the project transport system, i.e. their baseline.
- » A determination of the emission factors associated with all transport modes. The emission factors are determined as grams of CO₂-equivalent emissions per PKM (gCO₂-eq/PKM).

ACM0016 provides many details for determining the two elements above. Furthermore, Annex 4 to the methodology provides a detailed procedure for undertaking the survey, including statistical considerations and a default survey questionnaire.

ACM0016 also provides a step-by-step procedure for the determination of baseline emissions per surveyed passenger in terms of the following key variables:

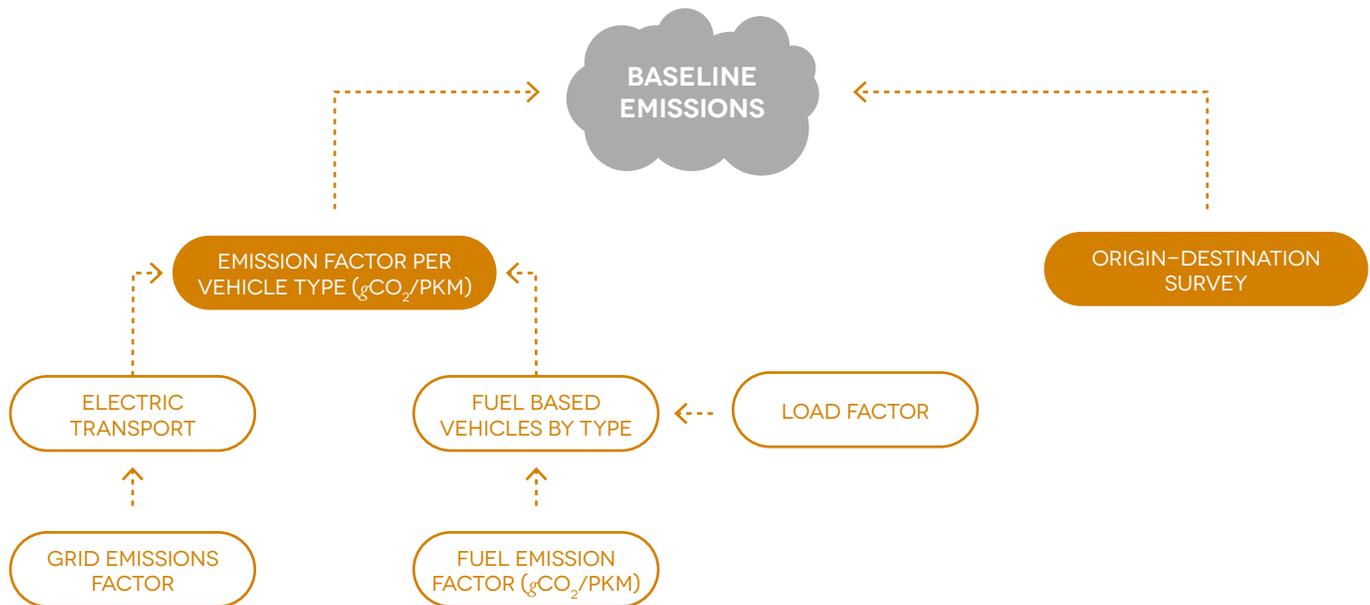
- » Emission factor per PKM of mode *i* (gCO₂/PKM)
- » Baseline trip distance per surveyed passenger *p* using mode *i* (PKM);

The next step is the determination of the emissions factor (gCO₂-eq per PKM) for each of the baseline transport modes. The methodology divides the modes into two categories:



SIMPLIFIED SCHEMATIC OF STEPS IN THE DETERMINATION OF BASELINE EMISSIONS

(figure 21)



- » Rail-based systems
- » Road-based systems

The emissions factor per PKM is calculated as the emissions factor per km divided by the occupancy rate, i.e. the number of passengers. However, the procedures for the determination of the emissions factor per km are more elaborated for road-based systems. ACM0016 provides two options:

- » Annual monitoring of the specific fuel consumption (SFC) of the respective vehicle category;
- » Use of a fixed technology improvement factor for the respective vehicle category, basically considering a 1% improvement in fuel efficiency per year.

For the determination of occupancy rates, Annexes 1, 2, and 3 of ACM0016 provide detailed procedures based

on visual occupation studies (all modes) and boarding-alighting surveys (buses).

Project emissions. The methodology specifies procedures for the determination of project emissions and classifies them into direct and indirect, the latter defined as in the case of AMS-III.U.

The principal inputs in determining project emissions are:

- » Fuel or electricity used by the project transport system;
- » Emission factors for the fuel or electricity.

If reliable data on total fuel consumption are not available, fuel consumption can be determined from the specific consumption of similar vehicles and total

distance traveled, based on a sample of vehicles on the project route.

Leakage. ACM0016 considers the same three sources of leakage as in AM0031, specifying very similar procedures for the determination of leakage emissions.

As seen from the previous sub-sections, CDM methodologies for projects involving modal shifts (e.g., AMS-III.U, AM0031, and ACM0016) are complex, requiring a great deal of effort and expense to monitor, collect and analyze data. The TEEMP tools provide an alternative to CDM methodologies that would be especially useful for ex ante estimations of baseline and project emissions and emission reductions.

Box 7: ACM0016 – Mass rapid transit projects

It is applicable for:

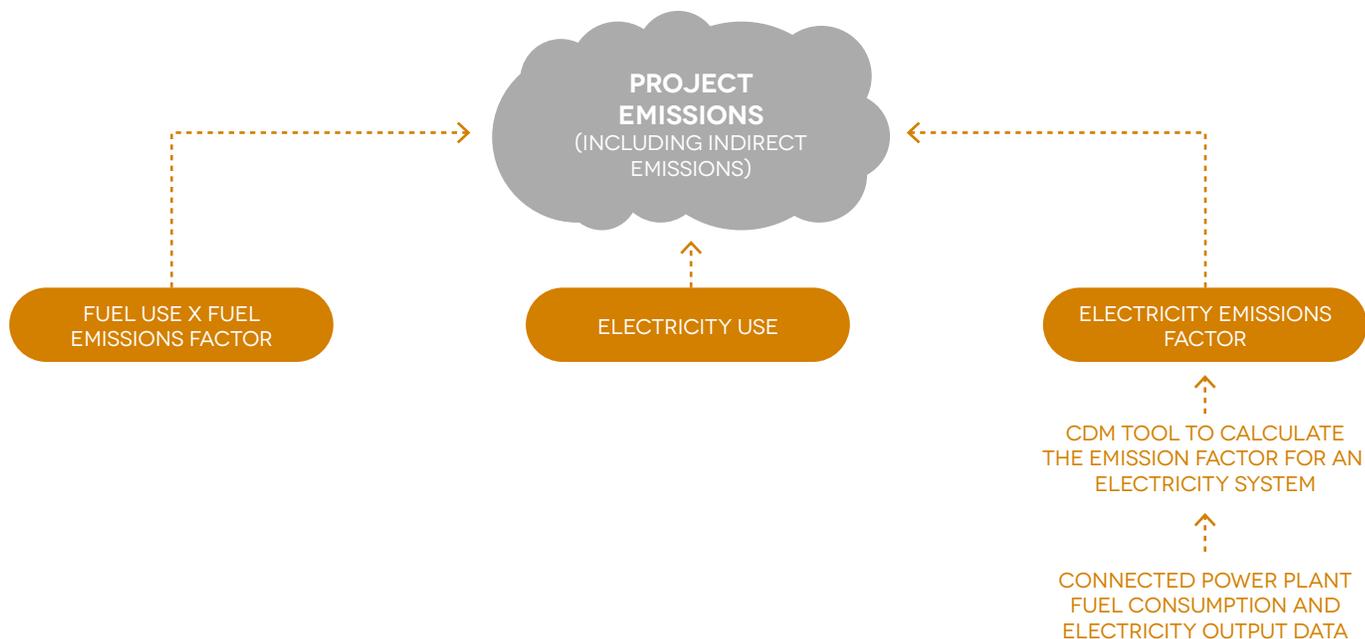
- » Installation of new BRT and/or rail-based systems
- » Urban or suburban trips
- » Passenger transport (only)
- » Passengers may complete their entire trip or only a part of it on the BRT or rail-based MRTS

It is not applicable for:

- » Freight transport
- » Operational Improvements of an existing bus lane or rail-based MRTS, i.e. end-use energy efficiency improvements
- » Fuel switching, e.g. from liquid petroleum fuels to CNG or electric powered transport
- » Bikeways
- » Inter-urban transport

SIMPLIFIED SCHEMATIC OF STEPS IN THE DETERMINATION OF PROJECT EMISSIONS

(figure 22)



Transport Emissions Evaluation Models for Projects

The Transport Emissions Evaluation Models for Projects (TEEMP) was developed for evaluating GEF projects.⁷⁶ TEEMP comprises a set of spreadsheets designed to determine changes in GHG and air pollutant emissions from transport projects. TEEMP was designed to allow for easy comparison of project vs. no-project scenarios and to calculate cumulative emissions reductions over the life of the project.

When compared to the CDM project methodologies, the TEEMP tools may be perceived as less rigorous and data intensive. However, they were specifically designed in order to be accessible to project proponents with limited data resources. TEEMP allows the use of default values and sketch tools to address data limitations when local data are unavailable. Box 8 describes basic assumptions taken when working with TEEMP.

Box 8: Assumptions used when calculating GHG impacts based on TEEMP

- » All GHG impacts are accounted for in CO₂eq units
- » Cumulative GHG emission reductions should be reported for the life of the intervention or project (at least 20 years)
- » Future GHG emission reductions should not be discounted
- » Project proponents should use as much locally available data as possible. When no data are available or reliable, conservative default values provided in the TEEMP should be used.

It is important to understand that TEEMP attempts to go beyond GHG impact estimation to include analysis of local co-benefits. Some of the co-benefits that TEEMP attempts to capture include the implementation of government policies to promote climate friendly investments, capacity building at the local level, leverage of private sector financing, etc. Furthermore, GHG impacts, supported by TEEMP, are measured at three levels: direct, direct post-project, and indirect.

Direct GHG impacts are those clearly associated with the actual intervention or project, i.e., emission reductions achieved within the project's boundary, which usually include a combination of improvements in vehicle fuel efficiency, GHG intensity of fuel used, transport activity, choice of mode of transport, and occupancy levels. Direct post-project GHG impacts are those that derive from the implementation of financial mechanisms – e.g. a credit guarantee facility or revolving funds – that continue to

76 – TEEMP was developed by ITDP, CAI-Asia, and Cambridge Systematics, Inc. The TEEMP toolbox and documentation are available at: <http://www.itdp.org/what-we-do/climate-and-transport-policy/transport-emissions-evaluation-models-for-projects/>

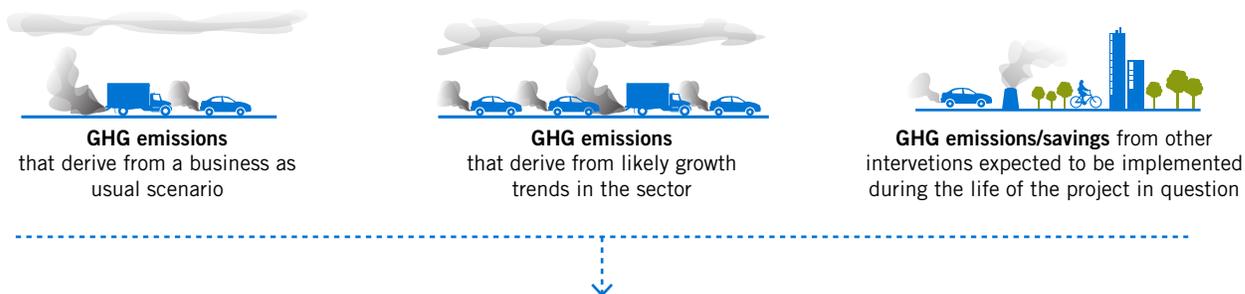
support direct investments post project lifetime that yield GHG emission reductions. Indirect GHG impacts have a different definition to the one used under the CDM, since under TEEMP they comprise emission reductions that derive from the replication potential of a successful project. The overall TEEMP approach is illustrated in Figure 23.

Below we review the TEEMP model for BRTs. In the process, we point out differences between this approach and the comparable CDM methodologies.

SEQUENCE OF STEPS REQUIRED TO IMPLEMENT TEEMP

(figure 23)

CALCULATE BASELINE GHG EMISSIONS



CALCULATE DIRECT GHG IMPACT

$$CO_2 \text{ direct} = E * c * I$$

Generally calculated as the fuel/energy saved or substituted (E) over the lifetime (I) of the project multiplied by the CO₂ intensity of fuel/energy (c).



CALCULATE INDIRECT GHG IMPACTS

This requires an expert's assessment of the likelihood that a project will be repeated in the same region or country within 10 years of the original project being complete.

The GHG impact of the likely project replications can be estimated through bottom-up or top-down approaches.

ESTIMATE POST PROJECT DIRECT GHG IMPACT

If financing of mitigation actions continue after the end of the GEF project, direct emissions reductions should be reported separately.

The GHG impact is calculated by extrapolating from the direct GHG impact of project implementation multiplied by a turn-over factor which describes the rate of reinvestment of the financial flows.

TEEMP model for BRT

The TEEMP BRT Model includes both a “shortcut” as well as a “full scenario” method for estimating the emissions impact from BRT projects, their infrastructure needs, and the resulting modal shift. The shortcut method is a low-confidence estimate that may be useful at early planning stages as it simply entails multiplying the proposed BRT corridor length by the average emissions reductions from several previously implemented projects of the same kind.⁷⁷ The full scenario method requires local and project specific data in order to produce a higher-confidence GHG impact estimate of the project.⁷⁸ Data requirements for the full scenario method for BRT projects are shown in Box 9.

As figure 23 shows, the full scenario method requires primarily an estimate of the number of users (ridership) for the BRT, route length, mode share, frequency, bus capacity and engine type, fuel, and average speeds, among other parameters. These data may be obtained from local surveys or from default values. The TEEMP Manual provides procedures for estimating ridership, based on the following parameters:

- » Price change with respect to existing bus systems, i.e. taking into account price elasticity;
- » Data on existing bus routes along the proposed BRT corridor, including:
 - Average speeds;
 - Average trip length;
 - Frequency and occupancy counts; and
 - Boarding and alighting counts;
- » Speed of BRT.

In this sense, the TEEMP model provides procedures for ex-ante estimation project and baseline emissions, i.e. before the BRT is constructed. The CDM methodologies

AM0031 and ACM0016 do not. However, these CDM methodologies include procedures and questionnaires for origin-destination surveys that may be applied to the TEEMP model.

While CDM methodologies only consider GHG emissions in vehicle operation, TEEMP also considers emissions generated from the construction of BRT infrastructure. TEEMP provides default values for construction material needs (tonnes of cement, bitumen, and steel) and emissions associated with them, allowing the user to apply more project-specific values when available.

Building construction has also been known to intensify along BRT routes, so that average trip length decreases. The TEEMP BRT model takes into consideration land use changes along its corridors.

The TEEMP model output includes parameters that were not considered in the CDM methodologies, e.g. PM and NOx emissions, which are important for air quality, especially in urban areas, but not directly relevant for climate change mitigation.

While public transportation improvement such as BRTs and Metros are covered by both CDM methodologies and TEEMP models, the latter provides procedures for several categories of measures that are not covered under the CDM, e.g. NMT policies, parking pricing, commuter travel reduction policies, eco-driving, and roadway capacity expansion or reduction (see Table 8). Below we review the TEEMP “bikeways” model as an example of NMT, as well as the TEEMP “Pricing” model. The full set of TEEMP tools are shown in Box 10.

77 – Institute for Transportation and Development Policy. (2011)
78 – Ibid

Box 9: TEEMP BRT: Data needs for full scenario method

Time scale: Base year, intermediate year and horizon year (BY, IY, HY, respectively)

For each of these years (BY, IY, HY)

- » Cumulative BRT km to be constructed
- » Ridership in BRTs
- » By vehicle type, including BRTs
 - Average speed (km/h)
 - Technology split (% of pre-Euro, Euro II, Euro III)
 - Fuel type (% gasoline and diesel)
 - Average occupancy (persons per vehicle)
 - Fuel efficiency at 50 km/h (km/liter)
 - Modal share (%)
 - Average trip length (km)

Fixed values, by vehicle type:

- » PM and NOx emission factors according to technology type
- Parameters BRT project
- » Components of BRT project
 - Infrastructure
 - Stations
 - Operations
 - Passenger information
 - » Fuel split for BRT fleet (% gasoline and diesel)
 - » Emission factor for BRT buses (gCO₂/km)
 - » Motorized mode shift factor
 - » Land use impact factor

Box 10: TEEMP Tool kit

- » Bike sharing model
- » Bike way model
- » BRT model
- » Commuter strategies model
- » Eco-driving model
- » Express way model
- » Metro model
- » PAYD mode
- » Pedestrian improvement mode
- » Pricing model
- » Railway model

Source: www.thegef.org/gef/node/9638

TEEMP model for bikeways

The TEEMP Bikeways Model provides a tool to estimate the GHG impacts of the development of bicycle lanes. Bicycle lanes or paths, as well as other NMT activities, attempt to shift transport away from GHG intensive modes.

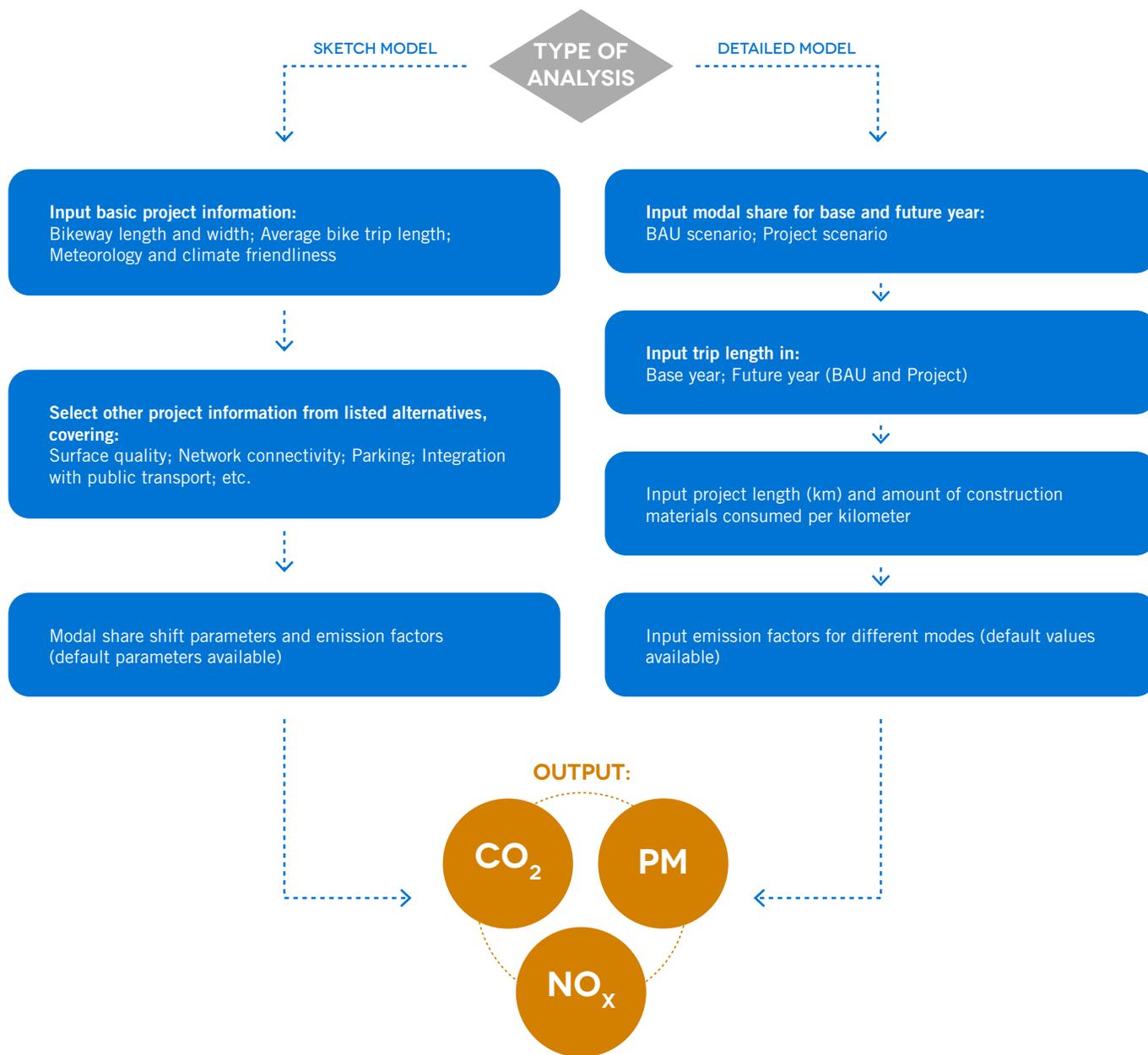
As in other TEEMP models, there is a simplified “sketch” version and a more detailed one. The sketch analysis provides a rough estimate where little local data are available, focusing primarily on two data parameters: the length of bike lanes and a default average trip length. The detailed model can use a great deal of local data as well as default values for those parameters that are difficult to determine in order to calculate BAU scenarios and project activity scenarios for various time horizons. The detailed model also captures GHG emissions from the construction of the bikeways. An overview of data requirements for both approaches is shown in Figure 24.

Mode shifts can be induced in a number of ways. The availability of BRTs and bike lanes reduces emissions by providing an alternative travel mode. Another approach to encourage mode shifting and reduce travel demand is through TDM strategies. Examples of demand management initiatives include transport pricing schemes, integrated transport and land use planning strategies, parking management, programs designed to avoid/reduce transportation such as telecommuting or car-sharing, etc.

Transport demand management strategies affect in general parameters “A” and “S” of the ASIF equation. Total transport activity “A”, denoted per VKM and/or PKM, would decrease if the demand management initiatives were effectively implemented. Likewise, modal share shifts “S” should be expected as a result of transport pricing initiatives. The TEEMP pricing model is discussed in detail in the next section.

SKETCH AND DETAILED APPROACHES IN THE TTEMP BIKEWAYS MODEL⁷⁹

(figure 24)



79 – Replogle, M., Punte, S., and Mejia, A. (2011)

TEEMP Pricing Model

The TEEMP Pricing Model considers three measures to reduce travel demand: (1) parking pricing, (2) parking density, and (3) company cars. Increased parking fees and the reduction of available parking spaces in urban areas reduce the use of private cars and encourage public transport. Employees have little incentive to drive less, if they have a company car. Eliminating the company car altogether or eliminating free fuel for non-business travel would lead to less car use.

In this case, TEEMP does not provide separate sketch and detailed models. Data requirements for the three travel demand models included in TEEMP Pricing are shown in Table 10. In general, data are required for the start year and the full-deployment year of the policy.

There are CDM methodologies and TEEMP tools for some of the mitigation options listed in Table 8. However,

neither TEEMP models nor CDM methodologies exist for many other options listed. Thus, existing models or methodologies need to be extended, or new procedures developed to cover these other measures.

Furthermore, a typical transport improvement project comprises many measures. For example, an urban passenger transport project could include new or expanded BRT, a new or expanded Metro, electric vehicles, bikeways, improved pedestrian access, parking restrictions, time-of-use road charges, etc. Similarly, freight transport policy could include fuel efficient vehicles, including vehicle scrapping and replacement, shifting from road to rail and/or boat, eco-driving, etc. The models or methodologies discussed above or listed in Table 8 do not address the impact of such combinations of measures on emissions.

Table 10. Data input requirements for three measures included in TEEMP Pricing Model

PARKING PRICE	PARKING DENSITY	COMPANY CARS
Daily vehicle trips	Daily vehicle trips to CBDs	Total number of company cars
Person vehicle trips	Number of Parking Spaces available in CBD	Annual average mileage for company car
Average percentage parking fee increase	Office and commercial space area in CBD or total CBD employment	Share of company cars with free fuel benefit
Percentage of parking affected by fee increase	City size	Targeted reduction in total company cars (fraction)
Income distribution of impacted travelers	Level of public transit	Targeted reduction in company cars with free fuel benefit (fraction)
Vehicular mode split		BAU total number of company cars
City size		
Parking location		
Level of public transit		

In the TEEMP tools and the CDM methodologies, mode changes are assumed to take place while the project activity proceeds. However, these are considered part of the baseline scenario, so that the emission reductions from the project activity under consideration are compared against a baseline, which includes the other changes taking place. For instance, the TEEMP BRT model considers a number of parameters that evolve over the modeling time horizon, such as technology split (from pre-Euro, to Euro II and Euro III), fuel efficiency, fuel type for baseline vehicles, etc. Similarly, the CDM methodology ACM0016 considers vehicle fuel efficiency improvement over time, as part of the baseline scenario.

Likewise, a city may undertake a series of mitigation activities over time. Thus, a city may implement a BRT project, where conventional buses and other vehicles are the baseline. Later the same city may implement a metro or cable car transport system, or both. For the determination of emission reductions for this later project, the baseline scenario would be the city with the BRT system. Thus the project scenario for the first project becomes the baseline for the second.

TEEMP-CITY is a recently developed estimation tool designed to evaluate the GHG impact of a multi-modal city plan by incorporating a) current and projected city developments and transport trends, b) proposed projects and investments, and c) impacts in emissions, time and fuel saved. It also allows for the evaluation of alternative scenarios. A more elaborate version could be developed with the level of detail available in the TEEMP BRT model.

Some transport mitigation measures, e.g. urban rail or intermodal freight improvements, require major infrastructure investments and take many years to fully implement. Others may be administrative measures, e.g. road pricing, and may be implemented quickly. The net effect of all measures that may be implemented is best determined by periodic, e.g. annual, determination of total emissions from the transport sector, i.e. GHG emissions inventories, which are discussed in the section below.

GHG Emissions Inventories

A GHG emissions inventory quantifies total GHG emissions. Inventories may be undertaken at the national level or may also be undertaken by cities, companies and other entities. In this case, an inventory would cover the transport sector, with a geographical boundary that can be as small as an urban area or as large as an entire country. For specific policies, e.g. an urban sustainable mobility plan, the geographical boundary would be naturally defined by the scope of the policy. In the following section we review issues for urban transport inventories.

Unlike TEEMP models and CDM methodologies, the purpose of a sector-wide GHG inventory is not to assess the impact on GHG emissions from specific transport projects or measures. Instead, the inventory provides an overview of all GHG emissions from the sector at the specific point in time the inventory is completed. The periodic recalculation of the inventory determines the trend of GHG emissions over time, reflecting the effects of all measures undertaken as well as other factors affecting GHG emissions in the sector, e.g. overall economic activity or world petroleum prices.

Urban transport GHG inventories

The World Resources Institute (WRI) recently reviewed methodologies for urban transport GHG inventories.⁸⁹ Urban inventories undertaken at a given time allow city officials and urban planners to quantify the magnitude of total emissions and its distribution among passenger and freight, and among modes. The inventory is also the starting point in the development of a mitigation strategy and should ideally include freight as well as passenger transport.

The issues addressed in the study by WRI include the following:

- » What is the appropriate boundary and how should trips that cross it be addressed?

- » Which transportation sub-sectors and trip types should be included in the inventory?
- » How often should an inventory be updated?
- » What is the best timeframe for assessing changes in emissions?
- » How should an inventory update account for increasing urban population?
- » What is the best way to report GHG emissions in an inventory?

Sector-wide GHG inventories adopt the practices and methods used for national GHG inventories, which are prepared following the rules and best-practices adopted by UNFCCC. In the following section, we review the link between transport inventories and national inventories.

National inventories

Annex I Parties to the UNFCCC report inventories of all GHG emissions annually, while Non-Annex I Parties submit these periodically as part of their National Communications to the UNFCCC. Procedures for undertaking national GHG inventories are well established.⁸⁰ Most countries also undertake national energy balances on a regular basis, and make the information publicly available. These quantify energy production by energy sources and demand by major consumption sectors, including transport. In some cases, transport energy consumption is broken down into passenger and freight. As noted above, CO₂ emissions from fuel consumption can be easily determined. While recent energy balances are available for most countries, the level of disaggregation of energy use in the transport sector varies. In general, data are available primarily for OECD countries.

Table 11 shows some key economic and transport indicators from Brazil, Mexico, Germany, and the United States, as examples. The upper half of the table shows two key transport “Activity” indicators:

- » Total road passenger transport (million passenger-km)
- » Road and rail freight transport (million tonne-km)

Since the above depend on the size of the economy, they can be shown adjusted by the next two indicators:

- » Road passenger transport per capita (millions passenger-km/capita)
- » Road and rail freight transport per unit of GDP (tonne-km/GDP)

While these indicators may be used to compare countries, they are much more useful to track progress within a country over time. Therefore these indicators are ideal for evaluation of the impact of urban mobility plans and other integral mitigation activities in the transport sector.

80 – IPCC Guidelines for National Greenhouse Gas Inventories. (2006)

Table 11. Key economic parameters and CO₂ emissions from transport for Brazil, Mexico, USA, and Germany (2007)

TRANSPORT AND THE ECONOMY	UNITS	BRAZIL	MEXICO	USA	GERMANY
Population	Million	191.60	105.68	302.09	82.26
GDP, PPP	Billion 2000 US\$	1,561.26	1,169.19	11,468.00	2,315.34
Road passenger km	Million PKM		449,917	4,486,974	933,387
Road and rail freight km	Million TKM		299,560	4,507,819	458,054
Road passengers (per capita)	PKM/capita		4,257.35	14,585.10	11,346.79
Road and rail freight (per GDP)	TKM/\$ GDP		0.26	0.39	0.20
CO₂ emissions					
CO ₂ from fuel combustion	Mt CO ₂	362.73	449.98	5915.46	829.55
... of which transport CO ₂		162.08	159.67	1953.62	179.8
Transport as percentage of total	%	44.7%	35.5%	33.0%	21.7%
Road	Mt CO ₂	132.26	139.84	1527.58	140.81
Rail	Mt CO ₂	1.86	2.09	39.74	1.26
Domestic aviation	Mt CO ₂	8.06	0.06	191.11	5.41
International aviation	Mt CO ₂	4.2	9.37	50.19	21.45
Domestic navigation	Mt CO ₂	4.29	2.93	11.04	0.52
International shipping	Mt CO ₂	11.44	2.69	95.96	9.66
Other transport	Mt CO ₂	0	2.69	37.99	0.7

Source: Adapted from: International Transport Federation (ITF), Reducing transport GHG emissions: Trends and Data 2010

Part 5

Summary & Conclusions

Key Findings – Current State of Practice in GHG Evaluation

LAC is facing high rates of motorization as it develops. This poses challenges not only for meeting global climate change mitigation objectives, but also for managing critical local problems including traffic congestion, air pollution, safety, and mobility across the income spectrum. To provide for mobility that supports development in a sustainable way, there is an urgent need to replicate and scale up sustainable low carbon transport polices and activities across LAC. The ASI approach provides a framework for developing sustainable transport plans. This monograph has provided an introduction to strategies that countries in LAC can use to reduce GHG emissions from transport following the ASI approach and an introduction to the concepts and tools that can be used to support GHG assessment of these strategies.

Climate change is key concern for many countries and financial institutions. Recent efforts by governments and institutions such as the IDB have focused on using financing tools to reduce GHG emissions, especially in developing countries. Such instruments can provide local governments with an incremental benefit that can help “tip the scale” for a project to move towards a low carbon intervention rather than a less sustainable alternative.

To take advantage of climate finance opportunities, however, project sponsors must provide funding agencies with evidence that the funded projects will reduce GHG emissions. Evaluation requirements for climate finance mechanisms vary widely and demand a wide array of approaches to evaluate GHG emissions and impacts over various spatial and temporal scales. While some finance mechanisms (such as CDM) have rigorous evaluation

requirements that many project sponsors will find hard to meet, others (such as GEF) have more flexible requirements that can be met with modest investment in data and analysis. The obstacles to transport sector participation in climate initiatives posed by existing evaluation requirements may be reduced in the future as more flexible funding mechanisms are developed. Project sponsors seeking climate finance should carefully examine the evaluation requirements of the various sources, and whether they will be able to meet these requirements, and should define an approach to data collection and analysis satisfying the needs of their likely partners.

Tools currently available to support GHG evaluation include sketch tools, advanced travel demand forecasting and simulation models, and emission factor models. Due to data limitations, it will often be necessary to use sketch level tools such as TEEMP, or ad-hoc methods developed by the project sponsor using available data. The accuracy of these methods can be improved over time as additional local data is collected.

In the long run, investment in institutional capacity to evaluate system performance – through the systematic collection of transport data and development of robust models for ex-ante and ex-post-project evaluation – will benefit cities and countries throughout LAC by enabling the use of more finance mechanisms and supporting development of high performance, sustainable, and modern mobility systems. Such investment, however, is not a pre-requisite to advancing towards more sustainable transportation.

Advancing the State of the Practice for Emissions Estimation

When considering what analysis is vital to supporting the development of sustainable mobility investment plans, it is important to consider the advice of John W. Tukey, who said, “far better an approximate answer to the right question... than an exact answer to the wrong question.”⁸¹ There are many evaluation frameworks that can be used to consider the impacts of transport projects and programs on emissions, but few of them give appropriate consideration to secondary, induced, and cumulative impacts, which are usually hard to bound neatly for evaluation. It is also useful to consider the advice of George E.P. Box, who said, “all models are wrong, but some are useful.”⁸²

Advancing sustainable mobility projects effectively requires locally grounded information sufficient to ensure effective project planning and design. Identifying short and longer-term impacts of a project on GHG in a manner certifiable under the strict requirements of the CDM requires considerably more data and information. Identifying the broader likely magnitude of impacts of a transport project or program on CO₂ and other emissions, including often profound secondary and indirect impacts, requires a different kind of analysis than that used for CDM. If such broader impact analysis is to be done rigorously and cost-effectively, it requires multiple types of local surveys and models and considerable sustained

institutional analytic capacity. While such analysis can be done in a one-off manner for a particular major project, this is less cost-effective. There are significant benefits to institutionalizing this capacity and applying it routinely to analysis of major projects and to periodic appraisal of large-scale investment programs and policies. The latter approach enhances the likelihood that the quality of technical analysis will improve over time through recurrent application and tool development, and makes it more likely that decision-makers and citizens will learn how to use these tools to support smarter transport system operations and wiser stewardship of investment resources.

Cities and national governments that seek to develop sustainable mobility plans but lack the data and models required for the more rigorous analysis provided by integrated land use, transport, and emissions models should:

1. **Develop a thorough inventory of existing data and models** that can support transport GHG analysis, identifying strengths and weaknesses in existing tools and information systems, their capacity to reasonably evaluate induced demand, changes in the composition and characteristics of motor vehicle fleets over time, and emissions inventories.

81 – Tukey, J. (1962)
82 – Box, J. (1987)

As much as possible, make this data publicly available to support collaborative development of analysis tools with universities, non-governmental organizations, system stakeholders and other potential partners.

2. **Develop an evaluation plan for initial ex-ante analysis of GHG impacts** of transport investments and programs using a combination of existing tools and local data with quick-response sketch models and transferable data parameters from other regions, complemented by quick-response local data collection as resources and time permit. Explore partnerships with universities, non-governmental organizations, and others to expand and sustain institutional capacity for monitoring, evaluation, and reporting.
3. **Develop and ensure funding for timely implementation of a transportation and urban development performance monitoring plan** that will provide the basis for creation of more robust baselines for measuring traffic characteristics, transport flows, vehicle fleets, emissions inventories, land use activities, and the trends in these over time. Set a target to invest 2–4% of transportation capital investment in better system monitoring, performance evaluation, and strategic planning analysis capabilities. Explore opportunities for fast payback in cost savings from improved system performance. Ensure that private sector investment contributes to developing these systems, rather than just to self-serving, one-off, project-focused studies that fail to link with each other or to build independent local institutional capacity. With such levels of investment, cities, states, and countries can in just a few years have reasonably effective

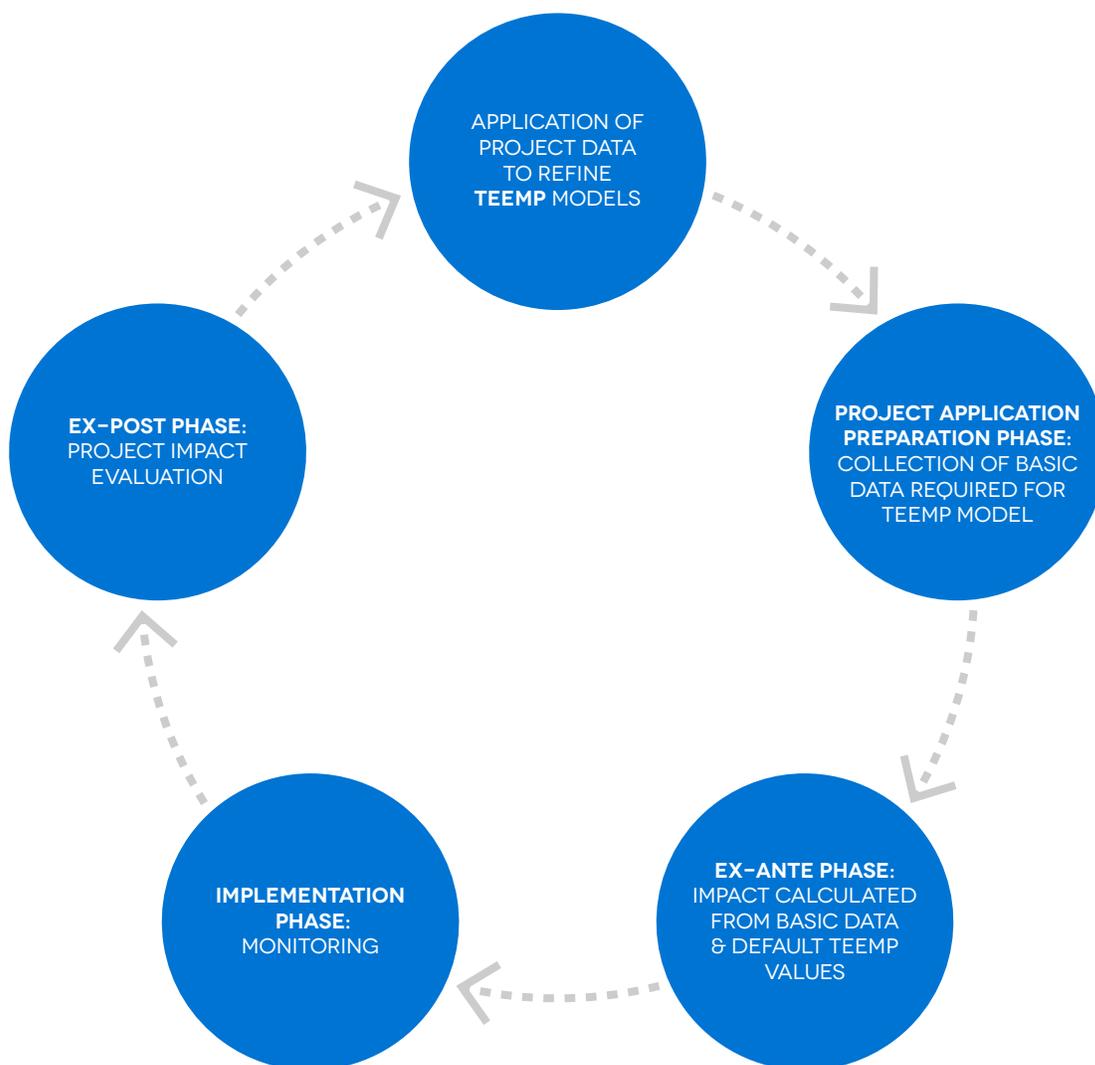
analysis tools that integrate representations of their transport and land use with emissions and natural resource impact analysis, with institutional capacity to use such tools for effective sustainable transport plan implementation at the city, state, and national level. The cost of data acquisition is dropping rapidly through use of vehicle and cell phone probes, low-cost GPS monitors, data mining, and crowd-sourcing techniques.

4. **Refine ex-ante analyses with additional local data and carry out ex-post evaluation** of project and program impacts. Use the information gained from evaluations to improve local understanding and contribute regionally-appropriate sketch model transferable parameters so future planning and analysis is better grounded in real world experience, as shown in Figure 25 using TEEMP as an example.

Ex-ante transport plan and project emissions evaluation typically relies more on default parameters, requires a lower degree of confidence, and provides estimates that are coarser and less reliable. Ex-post assessment, such as the monitoring and verification required for CDM project activities or the integrated transport, land use and emissions models developed from local data, typically rely on more measurements, and provide a higher level of confidence at a more fine-grained level of analysis. Moving from ex-ante to ex-post tools demands a higher cost and greater levels of complexity in the analysis framework, but these investments should be part of project budgets.

REFINEMENT OF TEEMP SKETCH MODEL PARAMETERS THROUGH APPLICATION AND ANALYSIS

(figure 25)



Source: GEF Manual for Calculating GHG Benefits of Transport Projects.
http://www.thegef.org/gef/GEF_C39_Inf.16_Manual_Greenhouse_Gas_Benefits

Placing GHG Benefits in the Context of Sustainable Mobility

To meet the needs of decision-makers and stakeholders, sustainable mobility analysis tools and monitoring systems should evaluate not only GHG emissions, but also other air pollutants, impacts on water quality, impacts on user costs and benefits, and other elements of transport system performance. Transport projects are in general pursued because they improve access or mobility, improve safety or reduce adverse public health impacts, support economic development, or some combination thereof. Transport projects and programs that are more sustainable advance all of these goals and also help reduce GHG pollution either in absolute terms or in comparison to BAU investment alternatives.⁸³

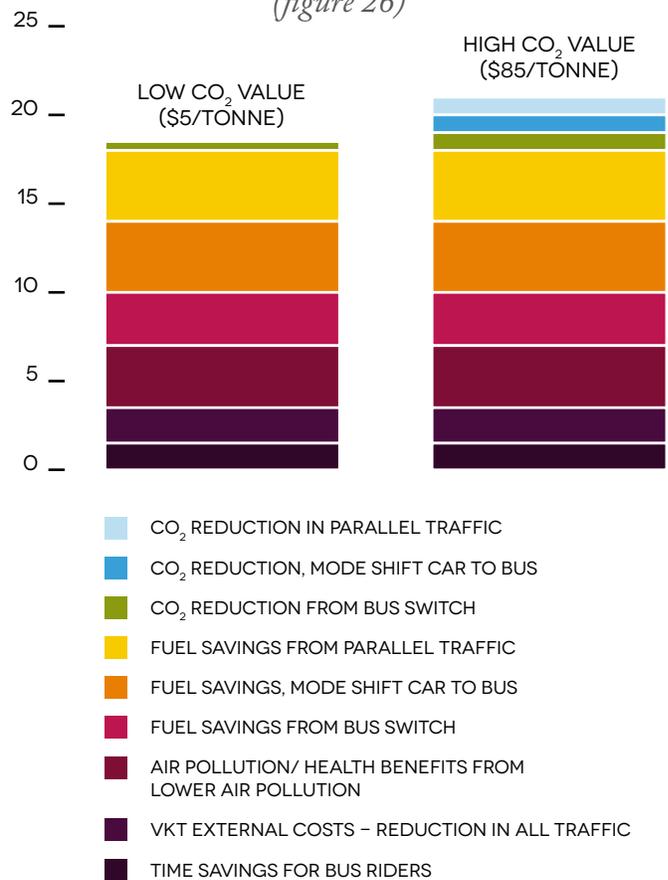
For example, as Figure 26 shows, a project-focused analysis of the early phase of the Mexico City BRT system found that the CO₂ benefits of the project were dwarfed by other benefits, especially by the value of fuel savings, even if CO₂ were to be priced at a high cost of US\$85 per ton avoided. Similarly, a top-down national analysis of potential CO₂ mitigation strategies for the United States found that motor vehicle user operating cost savings would far exceed the costs of implementing low carbon transport investment policies after only a short initial startup period.⁸⁴

Winning political and fiscal support for sustainable mobility investment and policy programs will be facilitated by better analysis of the distribution of diverse benefits and burdens of current and alternative future initiatives. Well-calibrated, comprehensive, integrated, micro-simulation based on land use and transport models are most likely to be capable of providing such analytic

support and should be a goal for institutional capacity development for effective regional planning and policy-making. But even in the absence of such tools, simple sketch models like TEEMP may be used to consider co-benefits, drawing on more default transferable parameters and expert analyst judgment to provide initial estimates.

VALUING THE BENEFITS OF MEXICO CITY'S METROBÚS BRT⁸⁵

(figure 26)



83 – For a fuller discussion of co-benefit estimation techniques, see: IGES. (2011)

84 – Cambridge Systematics. (2009)

85 – Lee Schipper et al. (2009)

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The Inter-American Development Bank launched the Regional Environmentally Sustainable Transport (REST) Action Plan in 2010 to provide guidance to client countries and to facilitate the mainstreaming of climate change mitigation and adaptation in IDB's transport operations. Initial activities have focused on building knowledge and capacity through international seminars and workshops, creating knowledge products for the support of sustainable transport, and training IDB staff and clients in sustainable urban passenger and freight transport.



Rising incomes in Latin America and the Caribbean portend rising use of motor vehicles, with attendant challenges to manage traffic congestion, air pollution, energy security, and global warming. International concern regarding the effects of climate change is leading to the creation of mechanisms to promote transport initiatives that reduce greenhouse gas emissions. In addition, there is increasingly widespread interest in more sustainable transport strategies that reduce GHG emissions and improve air quality and safety, while also providing access and supporting mobility and economic development.

This document is intended to assist planners in Latin America and the Caribbean in understanding how to assess the GHG emissions reduction benefits of sustainable transport projects, policies, and strategies.

